BULLETS & BOOZE:
ALCOHOL OUTLET ACCESS AND VIOLENT CRIME IN BALTIMORE CITY, MD

by
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Abstract

Background: The association between alcohol outlets and violent crime is well-established. However, the literature contains conflicting findings, which this dissertation assumes could be the result of poor measurement. It compares three measurement methods – counts, proximity, and spatial access – to determine how to best quantify alcohol outlet access and then uses the method that performs the best to determine the association between alcohol outlets and violent crime in Baltimore, MD. Lastly, this dissertation translates these findings for policy discussions using cost-effectiveness analysis to determine the number of violent crimes one could prevent, money one could save, and quality-adjusted life years (QALYs) one could preserve with alcohol outlet density zoning policies.

Methods: Chapter 3 tests a total of 32 models, using negative binomial regression for count outcomes and linear regression for continuous outcomes. Choropleth maps and Akaike's Information Criterion (AIC) guided determination of which model yielded the best fit for the data. Chapter 4 uses the spatial access methods from chapter 3 and linear regression to measure the association between alcohol outlet access and violent crime exposure in Baltimore, MD. Chapter 5 uses cost-effectiveness analysis based on the measure of association from Chapter 3.

Results: Greater alcohol outlet access was consistently associated with more violent crime. Spatial access measures contained the most statistical and conceptual advantages. Each 10% increase in access to alcohol outlets was associated with a 4.2% increase in exposure to violent crime. A 10% increase in access to off-premise and LBD-7 outlets, which are combined off- and on-premise licensed outlets, had a greater association with violent crime than access to on-premise outlets. Removing both the liquor stores in residential zones and the bars/taverns operating as liquor stores would prevent 781 violent crimes, save $57.6 million, and preserve 608 QALYs.

Conclusion: Greater alcohol outlet access is associated with higher exposure to violent crime. Accurate measurement of the alcohol environment is important for scientific and policy discussions and should become part of routine public health surveillance.

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Chapter 1: Introduction

Problem Statement

Alcohol is the most commonly used drug in the United States (US) [1]. In 2016, 50.7% of adults in the US drank alcohol in the past 30 days, 24.2% binge drank (i.e., consumed five or more alcoholic drinks for men and four or more alcoholic drinks for women on one occasion) in the past 30 days, and 6.0% drank heavily (i.e., men consumed an average of more than two alcoholic drinks daily and women consumed an average of more than 1 alcoholic drink daily) in the past 30 days [2]. Alcohol contributes to more than 200 International Classification of Diseases, 10th Edition (ICD-10) diagnoses [3]. Each year, there are approximately 88,000 alcohol-related deaths in the US [4], which makes alcohol the fourth leading actual cause of death in the US [5]. Excessive alcohol consumption (i.e., binge drinking, heavy drinking, drinking by pregnant women, and underage drinking) cost the US $249 billion in 2010, which equates to $2.05 per drink [6].

When it comes to drinking, environments matter. This dissertation seeks to provide greater theoretical, methodological and analytic clarity to key relationships in alcohol environments. Multiple reviews of the research literature consistently find that environmental features are both significant determinants of and key points of intervention for reducing excessive drinking [7-9]. These "upstream" influences often have more stable associations with the related health harms than proximal determinants such as personality traits or family history, rendering these influences more advantageous in terms of interventions [10]. Further, prevention efforts will likely fail if they do not address the mechanisms that encourage people to engage in the risky behaviors in the first place [10].

Where people get alcohol is one such key contextualizing factor of excessive alcohol consumption and, consequentially, related harms [11-13]. In particular, the *spatial access* of commercial alcohol outlets measures people's potential interactions with alcohol outlets in a geographic location, and it combines concepts of alcohol outlet *availability* (i.e., the number of alcohol outlets in an area) and *accessibility* (i.e., travel impedance to those outlets). Such calculations must disaggregate effects by types of alcohol outlets, because all outlets do not exert the same forces [14]. The crudest distinction separates *on-premise* and *off-premise* outlets. On-premise outlets serve alcoholic beverages for consumption on-site (e.g., bars, restaurants), and off-premise outlets sell alcoholic beverages for consumption at other locations (e.g., liquor stores). Approximately 76% of alcohol is purchased from off-premise stores while the remaining 24% is purchased for on-site consumption [15].

Contributions

This manuscript dissertation is comprised of six chapters. Following this introductory chapter, chapter 2 reviews the literature and sets an epistemological context for the original research presented in subsequent chapters. Chapter 3 compares common methods of calculating alcohol outlet access and violent crime, and the conclusions reached in this chapter set the foundation for research in chapters 4 and 5. Chapter 4 examines the association between alcohol outlet access and violent crime in Baltimore City. Chapter 5 determines the potential benefits of different alcohol outlet access zoning policies. Chapter 6 then discusses the findings from chapters 3 through 5 and makes recommendations for future research. Appendix 1 presents a detailed description of the methods used in chapters 3 through 5.

This literature review summarizes the theory, methods, and findings for spatial studies of the alcohol environment. It is organized into two main sections: preliminary and contemporary research. This distinction is necessary because the early research occurred before several technological and methodological advancements (e.g., geographic information services [GIS], and spatial statistics) needed to accurately measure spatial dimensions. Despite using flawed methods, the motivations and conceptualizations of the early research play a key role in understanding the trajectory of the field.

Chapter 2: Literature Review

Early Alcohol Outlet Availability Research

This section briefly summarizes early research on the effects of alcohol outlet availability on related harms, beginning with the theoretical underpinnings that paved the way for this body of research.

Theoretical Underpinnings

After the repeal of prohibition, Jellinek's medical model of alcoholism strongly influenced concepts of alcohol use and measurement [16]. Briefly, Jellinek distinguished types of alcoholics, including alpha alcoholics (i.e., those in early stages of alcoholism before they have the "disease" and before they have "lost control" over their drinking), beta alcoholics (i.e., drinkers in a more advanced stage than alpha alcoholics because they have physical effects other than physical or psychological dependence; these drinkers are also categorized as not having the "disease" of alcoholism), gamma alcoholics (i.e., alcoholics with hallmark symptoms of tolerance, dependence, and "loss of control"), delta alcoholics (i.e., gamma alcoholism with inability to abstain instead of "loss of control"), and epsilon alcoholics (i.e., the most advanced stage of alcoholism with hallmark constant cravings for alcohol) [16]. This framework ultimately guided health practitioners toward medicalizing "drunkenness," but it focused exclusively on the individual level and confined alcohol-related problems to issues of alcohol dependence [16]. The narrow focus on alcoholism was intentional; researchers minimized alcohol's social and health risks to distance themselves from the temperance movement [17].

The "sociocultural" or "integrationist" model introduced a limited concept of population-level alcohol use [18]. This model assumed that the United States had an unusually high prevalence of alcoholism because its society was ambivalent toward alcohol [17]. In contrast, this model argued that areas with lower rates of alcoholism tend to have cultural norms that discourage heavy drinking and encourage moderate drinking [19]. Consequently, the policy implications of the sociocultural model were moral education and reshaping cultural norms [17, 19]. The sociocultural model strongly opposed alcohol policies [17], and proponents fought for less restrictive minimum drinking ages, hours of alcohol sales, and sales of alcohol at grocery stores [20].

There were several key events in the 1960s and 1970s that propelled the shift in narrative from alcoholism to a population-level concept of alcohol-related problems. During the 1966 American Public Health Association

(APHA) meeting, Milton Terris presented a ground-breaking analysis on the association between population levels of alcohol consumption and liver cirrhosis mortality in which he concluded that alcohol policies could reduce liver cirrhosis mortality [17, 21]. In 1967, the National Institute of Mental Health-financed Cooperative Commission on the Study of Alcoholism published a report entitled *Alcohol Problems: A Report to the Nation,* which was one of the first major reports to define alcohol-related problems more broadly than alcoholism [17]. The next year, APHA published a *Guide to Community Control of Alcoholism,* which devoted two pages to discussion of laws and regulations that could prevent alcoholism [22]. In 1975, Bruun's seminal "Purple Book" called *Alcohol Control Policies in Public Health Perspective* first suggested evidence-based methods of reducing alcohol-related problems without focusing on cultural norms or education [23]. Finally in 1979, the World Health Organization published an expert committee report that concluded that alcohol dependence comprises only a small portion of alcohol-related harms [24]. This argument summarizes the prevention paradox: while dependent drinkers experience the highest rates of alcohol-related harms, the majority of alcohol-related harms at the population level stem from non-dependent drinking because non-dependent drinkers far outnumber dependent drinkers [17].

With these developments, the distribution of consumption model replaced the sociocultural model in the mid-1970s. The distribution of consumption model is based on Sully Ledermann's observation that, in the absence of individual-level controls, alcohol use is unimodal, positively skewed, and log-normal [17]. In other words, there are fewer drinkers at each successive level of per capita consumption [17, 20]. The unimodal concept was revolutionary, because it meant that all alcohol consumption existed on a continuum and alcoholics did not have a separate curve [17]. This made it possible to advocate for alcohol policies, because the argument that alcohol policies could reduce heavy drinking and prevent alcohol-related harms held greater potential if alcoholics were conceptualized as outliers on a continuum rather than a separate population [17]. Thus, the goal of the distribution of consumption model was to decrease mean per capita consumption in order to reduce alcoholism (or shift the curve to the left) [20], which was based on Ledermann's observation that mean per capita consumption tends to correlate with heavy drinking prevalence [17].

These perspectives shaped the early research on alcohol outlet availability. Jellinek's concepts determined the outcomes of interest; studies focused almost exclusively on alcoholism [25-29], proxies for alcoholism (e.g., cirrhosis mortality and other outcomes as defined by the "Jellinek formula") [25-27, 30-33], and symptoms of alcoholism (e.g., arrests for public intoxication) [26, 30, 31]. Similarly, other researchers used the distribution of consumption model to examine per capita consumption as a proxy for alcoholism [32, 34]. The effects of the sociocultural model were most evident in the method, dubbed "social area analysis", that researchers used [26, 30, 31]. These analyses argued that changes in outcomes of interest could be traced back to differences in social rank (i.e., "the objective factors of social class like occupation, education, and income"), urbanization or lifestyle (i.e., "the way of life chosen by the population whether it is the 'family-committed life' in the single-dwelling-unit area or the life of the working couple in the apartment house area"), and racial/ethnic cultural backgrounds [35]. Thus, early studies primarily focused on cultural dimensions that the sociocultural model indicated determined alcohol use, and alcohol outlet availability was relegated to ad hoc subanalyses [30, 31, 33].

Methods & Findings

Early studies of alcohol outlet availability were largely an exercise in trial and error. Smart (1977) was among the first to quantify alcohol availability nationally using an eight-item scale based on a self-proclaimed "not scientific" method published in *Medicine in the Public Interest* [36]. This scale included several different types of physical and temporal availability, including minimal legal purchase age, limits for off-premise sales, limits for on-premise sales, on-premise availability, limits on Sunday retail sales for on-premise sales, weekday closing hours for on-premise sales, limits on Sunday retail hours for off-premise sales, and weekday closing hours for off-premise sales [34]. Though these measures were quite heterogeneous, Smart weighted all eight equally [34]. Subsequent researchers questioned the internal properties of Smart's scale and proposed alternative measures, which often limited the concept of availability to one or two of Smart's original eight categories [27, 28]. Using these more limited definitions, researchers determined that the association between alcohol outlet availability and related harms differed by type of outlet [30], and that physical availability could not and should not be restricted analytically to a single dimension [25, 33].

Like the operational definition of alcohol outlet availability, the unit of analysis of the early alcohol availability research evolved over time. Many of the early studies were national [27, 28, 33, 34, 37] or multi-state in scope [25], using states as the unit of analysis. Some of these studies found a significant association between outlet availability and related harms despite small sample sizes [25, 27, 28] while others did not [29, 34]. Consequently, researchers questioned whether heterogeneity across and within states' sociodemographic factors, drinking patterns, and outlet distributions caused these conflicting findings [30, 38]. Gradually, studies chose smaller units of analysis, often moving first to counties [26, 30, 39, 40] or cities [31, 41, 42].

Methodologically, most of the early studies relied on basic analyses like correlations [25-27, 30, 31, 33, 34], chi square tests [32], and ordinary least squares (OLS) regressions [27, 28, 30, 33] to establish cross-sectional associations. Wagenaar advanced the field methodologically through his rigorous analyses of natural experiments of privatization [43-45]. Before Wagenaar, such analyses had yielded divergent findings; Smart (1986) concluded that introducing wine to grocery stores in Quebec did not increase wine consumption, Macdonald (1986) concluded that wine consumption increased in three of four states (i.e., Idaho, Maine, Washington, and Virginia) that privatized wine sales, and Mulford (1990) concluded that privatizing wine sales in Iowa did not change wine consumption or fatal car crashes. However, these initial evaluations used OLS regression to analyze longitudinal data, which violates the assumption of independent observations [32, 46, 47]. Using an interrupted time series design controlling for autoregression, seasonality, and trends over time, Wagenaar et al (1991) found that privatizing wine sales increased wine consumption by 93% in Iowa and by 43% in West Virginia [43].

Ultimately, the findings from early studies enabled researchers to argue that alcohol outlet availability was within the scope of public health [28]. Once enough studies accumulated significant findings, authors began to hypothesize that alcohol outlet availability may play a role in generating alcohol-related problems [31] and limiting the number of alcohol outlets may reduce consumption and related harms [33]. However, this was not the universal consensus. Critics argued that alcohol outlet availability may reflect rather than control the underlying demand for alcohol [48, 49]. They also used aggregate data to contend that reducing the physical availability of alcohol may unintentionally exacerbate an individual's risk for alcohol-related harms [50, 51]; however, these claims fall victim to the ecologic fallacy, which states that findings at the aggregate level may not hold at the individual level.

Transition to Contemporary Alcohol Outlet Density Research

Studies began using smaller units of analysis (i.e., census tracts [CTs] or census block groups [CBGs]) in the late 1990s [52, 53]. Around this time, Gruenewald (1996) and Scribner (1999) provided conclusive evidence that smaller units of analysis yielded more stable estimates [54, 55], and the field operationalized this in promoting the use of CTs [55-61]. Scribner (1999) articulated the benefit of smaller units of analysis as generating relatively homogenous units; the larger the units, the more likely they are to include diverse populations [55] that would make them vulnerable to aggregation biases. Further, Speer, Gorman, Labouvie, and Ontkush (1998) demonstrated that moderate correlations at the CT level were stronger at the CBG level [52]; despite this, studies only rarely used CBGs [62]. Still, the conflicting findings that plagued early alcohol outlet availability research [27, 28, 30, 34, 42, 63] began to subside after researchers started using smaller units.

Also around the year 2000, methods emerged to permit GIS mapping [55] and detect and adjust for positive spatial autocorrelation (i.e., the degree to which objects – be they alcohol outlets, harms such as violence, or neighborhood disadvantage – cluster in space) [62, 64, 65]. Prior to this, researchers were unaware of the significance of spatial autocorrelation on inferences [55], though they understood temporal autocorrelation (i.e., the degree to which objects are related in time) [43]. Briefly, positive spatial autocorrelation violates the OLS regression assumption that the units are all independent, and it can lead to misestimated standard errors, which (in the presence of positive autocorrelation) can ultimately result in a type I error. Later research argued that the distal effects of alcohol outlets were significant [66-68]; in other words, alcohol outlets in one CT can determine health outcomes in adjacent CTs. This is especially important when measuring the harms for off-premise outlets, because there are often lags between the locations of purchase, consumption, and harm (this is often termed "diffusion bias") [69].

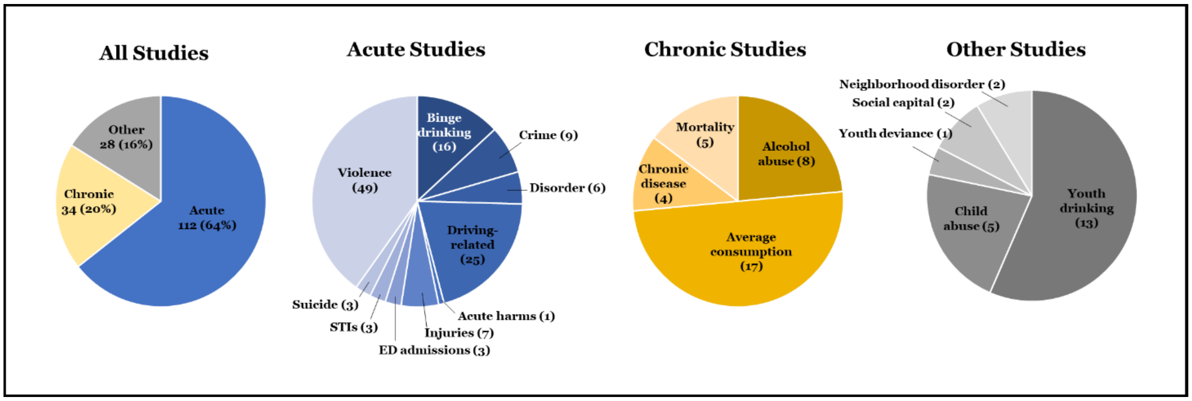
Contemporary Alcohol Outlet Density Research

This section summarizes the theories, methods, and findings from the public health alcohol outlet research that uses advanced methods, and most of the studies were published since 2000. Unless otherwise noted, this section only includes findings from studies that account for positive spatial autocorrelation to avoid presenting research that potentially includes false positives.

Livingston (2007) offers a helpful framework for conceptualizing the harms related to alcohol outlets. He disaggregates these harms into proximal and amenity harms [14]. From this perspective, greater alcohol outlet availability and accessibility cause proximal harms by increasing alcohol consumption, which in turn increases related harms through alcohol's intoxicating and toxic effects [14]. These harms accumulate until they reach a saturation point [14]. However, greater alcohol outlet access causes amenity harms by bringing drinkers together in close proximity, and these harms continue to accrue linearly without reaching a saturation point [14].

As shown in Figure 2-1, the research base predominantly focuses on the proximate harms of alcohol outlet access, like violence [14, 52, 58, 61-63, 65-68, 70-101], other injuries [64, 76, 102, 103], alcohol-related hospitalizations [104, 105], drink driving and traffic crashes [41, 66, 77, 106-111], sexually transmitted infections (i.e., gonorrhea, HSV-2, and HIV) [53, 112-114], marijuana use [115], and child abuse/neglect [60, 116-118]. By comparison, only a few studies have focused on amenity harms (the subset of acute harms called "disorder" in Figure 2-1) [119, 120].

Figure 2-1. Alcohol Outlet Study Topics



NOTE: Based on table presented by Holmes et al. (2014) and updated to include more research since April 2014. "Other" studies are studies where researchers could not determine whether the harms were acute or chronic.

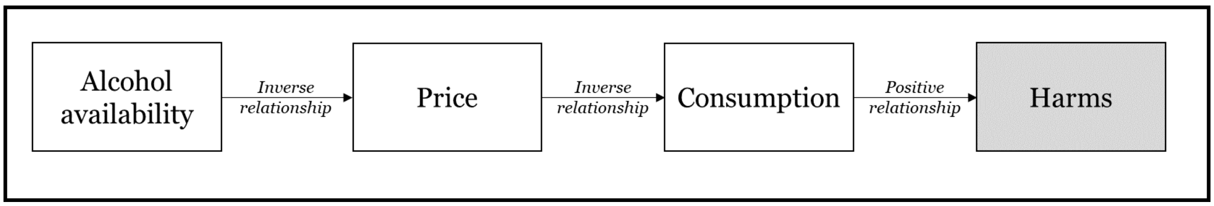
Theories

Before exploring the methods and findings in this field, one must consider plausible biological and social pathways for why increased access to alcohol outlets would cause related harms. Early on, many of these theories assumed that the association was mediated by increased consumption; that is, people who live near more alcohol outlets drink more alcohol and this increased consumption leads to harms. Later researchers expanded this concept to posit pathways that did not rely on increased alcohol use. This section briefly summarizes three of the main theories underlying alcohol outlet research: availability theory, routine activity theory, and social disorganization theory.

Availability Theory

Availability theory is the first and most commonly used theory to explain the harms associated with alcohol outlet access [72, 81, 95, 96, 121, 122]. Availability theory asserts that greater physical and social availability of alcohol increases alcohol consumption and (therefore) alcohol-related harms [123]. Availability theory contends that increasing perceived physical availability of alcohol increases consumption by decreasing price through competition among retailers and reducing drinkers' costs through shorter travel times [56, 120, 124]. Stockwell and Gruenewald (2004) argue that increased availability only increases alcohol consumption if it reduces the "full price" (i.e., the actual price of the beverage plus the convenience costs required to obtain it) or alters "routine drinking activities" (i.e., the ways in which people drink alcohol). Further, the increases in population-level alcohol consumption will be driven by greater consumption in specific segments, and the resulting rise in alcohol-related harms will be borne by those with the greatest risk (as determined by routine drinking activities and drinking patterns) [125].

Figure 2-2. Availability Theory



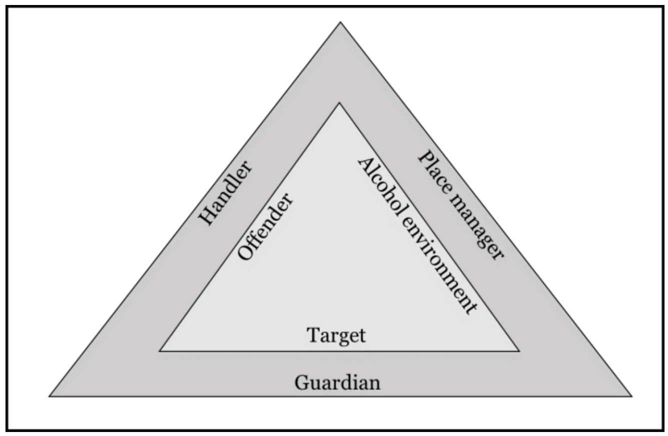
Findings that associate increased alcohol outlet availability with greater alcohol consumption support this view [126-129]. A few studies have tested availability theory by using sales or consumption data as potential mediators of the association between alcohol outlet availability and related harms. However, these studies are rare because it is difficult to obtain sales data or individual-level drinking data within small geographic units. Using data from 32 US colleges, Scribner et al. (2010) found that the association between alcohol outlet availability and violent crime attenuated after adjusting for student drinking [130]. This implies that consumption mediates the association between alcohol outlet availability and violence. However, Liang and Chikritzhs (2011) analyzed data from 140 local government areas in Perth, Australia and found that the association between alcohol outlet availability and violence held after controlling for sales volume [99], which suggests that other pathways must be explored as well.

Overall, availability theory inspired the initial investigations into harms that stem from increased physical availability of alcohol. However, as Livingston et al. (2007) argue, availability theory alone cannot explain the variation in the findings from this field [14]. Further, if one considers that alcohol consumption causes at most 50% of violent crimes, then the associations cited between alcohol outlet access and violent crime may result in even larger increases in alcohol-attributable incidents than is the case for other harms [131].

Routine Activity Theory

Roncek & Maier conducted a 1991 study using block-level data from Cincinnati that was ahead of its time conceptually. Drawing on routine activity theory and urban sociology, Roncek & Maier argued that characteristics of bars/taverns as well as their patrons/staff promoted crime independent of alcohol consumption [132]. This is consistent with routine activity theory, which asserts that crimes occur when likely offenders and susceptible targets interact in environments in the absence of a capable guardian (who would protect the target), a handler (who would restrain the offender), or a place manager (who would regulate the environment) [133]. Thus, alcohol outlets could facilitate crime by bringing drinkers, who are prime candidates for targets and offenders, together and creating opportunities for violence [7, 132]. At some level, this means that alcohol outlets function just like any other type of business; they draw in a stream of customers. However, that stream can spark violence when it is comprised of drinkers [95]. Alcohol outlets also possess unique criminogenic properties from a routine activity perspective. For example, on-premise alcohol outlets are popular among violence-prone populations (e.g., young males) and are often located in areas with reduced guardianship (e.g., retail districts) [79]. Further, on-premise patrons are more likely to become motivated perpetrators after consuming alcohol because of alcohol's disinhibiting effects [60, 79].

Figure 2-3. Eck's Crime Triangle



Ultimately, routine activity theory champions that off-premise outlets have a stronger association with violent crime than on-premise outlets do. This is because the place managers have very different roles in on- and off-premise outlets. Place managers in off-premise outlets only observe patrons briefly at the point of sale, but on-premise outlets have staff who can function as place managers [81, 134, 135]. Further, staff in many off-premise alcohol outlets serve patrons from behind a plexiglass wall, thus reducing the interaction between the staff and customers and reducing the capacity to effectively manage the environment [90]. Off-premise outlets or adjacent parking lots can also act as de facto bars/taverns without place managers in urban areas [96]. To date, the evidence supports this hypothesis; most cross-sectional studies comparing on- and off-premise density with violent crime found a greater effect for off-premise density [61, 79, 90, 93, 95, 122, 136-138].

Routine activity theory also argues that some on-premise outlets may carry heightened risk. Gruenewald argues that people "use" alcohol outlets in different ways, based on how they conduct their routine activities [66]. Thus, younger, unmarried people are more likely to patronize on-premise outlets while older, married people are more likely to patronize off-premise outlets [66]. In the end, the relationship between a place and violence will depend on how that location constrains or facilitates crime through physical, economic, social, and legal characteristics. Thus, the risk for violence could arise from the unique combinations of people who interact in alcohol outlets and the specific constraining or facilitating components of these locations [66]. Similarly, motivated offenders consider the inherent opportunities of specific locations (e.g., whether they fit in) when preparing to commit violent acts [138].

Overall, routine activity theory contributes pathways for how alcohol outlet availability can cause crime independent of alcohol consumption. In addition, it offers a conceptualization of spatial relationships between alcohol outlets and violence. Some patrons may purchase alcohol, consume it at home, and then commit a violent act while others consume the alcohol close to the point of purchase and then commit a violent act near the outlet [96]. This suggests that the spatial relationship between alcohol outlets and violent crime will depend on the type of outlet and the type of offender.

Social Disorganization Theory

Social disorganization theory is another place-based theory based on the work of Stark (1987) and Sampson et al. (1997) [133]. Stark et al. proposed an ecological theory of deviant places that associates structural characteristics of neighborhoods with adverse outcomes through their effect on the area's "moral order" such as "loss of control" [139]. Sampson et al. proposed an ecological model, which posited that collective efficacy (i.e., "social cohesion among neighbors combined with their willingness to intervene on behalf of the common good") mediates the association between neighborhood and violent crime [140]. Thus, higher levels of neighborhood disorganization can inhibit informal social control (i.e., the ability of residents to realize and enforce shared goals in a way that regulates individuals' behaviors) and social organization, which in turn may fuel violent crime [140].

Figure 2-4. Social Disorganization Theory

Alcohol outlet density researchers working in this vein argue that "broken bottles and bars" operate just like "broken windows" to undermine informal social control [62, 65, 135, 141]. This suggests that some alcohol outlets attract people who establish an atmosphere of immoral or illegal behavior, regardless of whether they are drinking [101]. These socially disorganized areas attract crime because they lack the controls to effectively regulate and prevent these behaviors [142]. Consistent with this idea, researchers have analyzed the alcohol environments in "hot spots" (i.e., areas where violence or crime cluster) [132]. Researchers conclude that alcohol outlets, drug arrests, and violent crime tend to cluster in the same areas [61, 70].

Like routine activity theory, social disorganization theory hypothesizes that off-premise outlets should have a stronger association with violent crime because they can serve as places for unsupervised social gatherings. From the social disorganization perspective, these de facto open-air taverns breed disorganization and undermine informal social control. Thus, the association between alcohol outlets and disorganization could be bidirectional; alcohol outlets may be more likely to move into disorganized areas because these areas have less political power, but alcohol outlets may also contribute to social disorganization by their role in the neighborhood [92, 143].

Researchers often test social disorganization theory using statistical interactions. Socially organized areas should have lower levels of violence because residents in these areas can exercise informal social control over patrons and outlet staff to act in more socially responsible ways and law enforcement personnel would pay greater attention to violence in these areas [92]. Several studies have found stronger effects of alcohol outlet availability on violent crime in socially disorganized areas [79, 92, 144]. For example, Gruenewald et al. (2006) studied 1,637 ZIP Codes in California and found that higher on-premise alcohol outlet availability in stable, high-income neighborhoods and immigrant Hispanic neighborhoods was associated with lower levels of violence but greater numbers of on-premise outlets in unstable, low-income neighborhoods were associated with higher levels of violence [79]. Similarly, using data from 298 census block groups in Cincinnati, Ohio, Pridemore et al. (2012)

found that the association between alcohol outlet availability and assault is weaker in areas with greater social organization (i.e., areas with higher percentages of households in poverty, with female heads of the household, and occupied by renters) [92].

In conclusion, social disorganization theory contributes potential confounders and effect measure modifiers. Building on the hot spot literature, subsequent research began adjusting for drug arrests [90, 98, 137, 145], while others also adjusted for gang- and narcotics-related homicides (as a proxy for gang activity) [100] as well as weapons arrests [98]. More generally, it became standard for research to adjust for proxies of social disorganization, like unemployment, median annual household income, poverty, welfare/public support, female-headed households with children, vacant houses, and percent of households that moved in the last five years.

Implications for Analyses

Ultimately, researchers operationalize these theories using combinations of variables in statistical models. Each of these theories points to different confounders and mediators (see Table 2-1). At a high level, availability theory uses variables that indicate whether physical availability of alcohol translates to increased alcohol sales and consumption. Routine activity theory identifies variables that indicate what types of people interact at alcohol outlets, particularly individual-level characteristics associated with violence perpetration (e.g., male, young). Social disorganization theory measures proxies for social disorganization (e.g., unemployment, poverty, gang presence).

Table 2-1. Key Alcohol Outlet Access Variables by Theoretical Orientation

Theory	Key Variables
Availability Theory	Alcohol consumption Alcohol prices Alcohol sales
Routine Activity Theory	Age Land use Sex/gender
Social Disorganization Theory	Drug arrests Education Female-headed households Gang presence Owner-occupied housing Poverty Racial/ethnic composition Residential mobility Unemployment Vacant households Weapons arrests Welfare/public assistance

Methods

The string of studies replicating Scribner, McKinnon, & Dwyer's 1995 analysis of alcohol outlet availability and violent crime using city-level data from Los Angeles, CA provide an interesting example of the progression of methods in alcohol outlet availability research [42]. While most of these initial studies did not adjust for spatial dependence, the evolution of the analyses provides insight into the development of the field's methods. Scribner, McKinnon, & Dwyer (1995) used city-level data and OLS regression to model the association between alcohol outlet availability and violent crime in Los Angeles. Their included covariates are consistent with social area analysis and can be categorized as social rank (percent unemployed, median home value), urbanization/lifestyle (city population, family composition, percent female-headed households, and the ratio of males aged 20-29 years to males aged 40-49 years), and racial/ethnic cultural backgrounds (percent African American, percent Hispanic). Scribner, McKinnon, & Dwyer first analyzed data for urban cities and found that a 1% increase in on-premise outlet availability was associated with a 0.36% (+/- 0.09%) increase in violent crime, a 1% increase in off-premise outlet availability was associated with a 0.56% (+/- 0.21%) increase in violent crime, and a 1% increase in total outlet availability was associated with a 0.62% (+/- 0.14%) increase in violent crime [42].

Scribner, McKinnon, & Dwyer's original analysis sparked interest among researchers, and several other researchers attempted to replicate their findings in other geographic locations. Gorman, Speer, Labouvie, & Subaiya were the first to replicate this study in 1998 using data from 223 municipalities in New Jersey, but they did not find an association, likely because of the geographically large unit of analysis [63]. Speer, Gorman, Labouvie, & Ontkush replicated this study again in 1998 using CT (n=91) and CBG (n=217) data from Newark, New Jersey [52]. They detected an association at both levels and ultimately concluded that one would have to increase median annual household income by 5% or reduce unemployment by 8% in order to reduce violent crime to the level that a 1% decrease in alcohol outlet availability would bring [52]. However, it was Gorman, Speer, Gruenewald, & Labouvie's 2001 replication study that demonstrated the benefits of more rigorous methods [62]. This time, Gorman's team used CBGs (n=98) as the unit of analysis and generalized least squares (GLS) regression to account for spatial dependence in the analysis [62]. They concluded that alcohol outlet availability explained more variance than any other covariate [62].

In the end, this string of replication studies demonstrates that the methods used in alcohol outlet access research determine the researchers' ability to make inferences. In light of this, the following section briefly outlines the data sources and methods used in this field as well as the strengths and limitations of different methodological choices.

Data Sources

The first methodological decision researchers must make is from where to obtain data. This decision ultimately determines which construct(s) researchers can measure and the types of analyses that are possible. Alcohol outlet access research often uses administrative data, likely because these data are readily available from licensing agencies. However, this arrangement means that researchers cannot obtain a single dataset with information about both alcohol outlet locations and health outcomes, because agencies with oversight of liquor licenses often do not collect health data. This forces researchers to combine datasets, and the underlying assumptions and strengths/weaknesses may differ across datasets [61, 70]. Table 2-2 below summarizes the strengths and limitations of common data sources used in alcohol outlet access studies.

Table 2-2. Strengths and Weaknesses of Data Sources

Construct	Data Source	Strengths	Limitations
Alcohol outlet access	Liquor licensing regulatory body	Data are available and often public record	Data were often not designed to be analyzed for public health purposes, so key variables might be missing or unavailable
	US Census Bureau Business Register	Data are available and often public record	Filing rules differ by state
			Public use files provide counts per ZIP Code
Violent crime	Local police	Data are available and often public record	Police operations (e.g., which parts of a community they patrol, number of officers on duty, and recording practices) determine trends in police data [146-148]
	Hospitals	Detailed hospital records exist, and researchers can often obtain them through data requests	These records provide the victim's residential address instead of the assault location
			Assaults requiring an overnight hospital admission will be biased to include the most severe assaults
		A subset of violent crime not reported to police may appear in hospital records [149]	Hospital records often only include a ZIP code for patient residential address, particularly if the hospital records are public and have been masked

Construct	Data Source	Strengths	Limitations
		E-codes have high sensitivity and specificity in patient follow-up studies [150]	E-coding is more complete for mortality than morbidity [151] and the quality of E-coding can also vary across states and countries [151]
	Vital records (e.g., death certificates)	Most complete data source for homicides	No data on the perpetrator and limited data on circumstances (e.g., weapon used, location)
	National Police/Law Enforcement Sources (e.g., FBI)	Data are available and often public record	Lower coverage, fewer details, and more inconsistent reporting for non-fatal crimes
		Uniform Crime Reports cover approximately 90-95% of the US population and cover about 85% of homicides	Limited details on homicide perpetrators, in particular alcohol use
			Coverage varies across time and space; in particular, there can be additional non-response bias because it is a voluntary reporting system
	National Violent Death Reporting System	Includes data on unintentional shooting deaths and suicides in addition to homicide	Only includes data for 40 states
		Combines police and medical examiner data	Data availability and completeness depend on relationships between local (e.g., police), state (e.g., state health department), and national organizations (e.g., NVDRS)
		Includes details about the victim and alcohol use	

Quantifying Alcohol Outlet Access

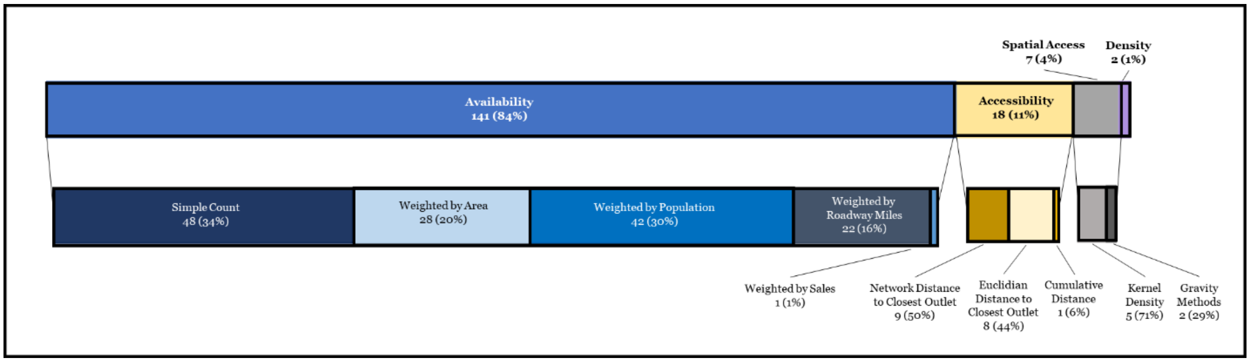
At a fundamental level, these studies all aim to quantify the alcohol environment. As the alcohol environment is a social construct, researchers must clarify what specific dimension(s) of the environment they are measuring. Drawing on conceptual research from other fields, one could argue that there are five dimensions of the environment that describe the degree of fit between a person and the environment: availability, accessibility, affordability, acceptability, and accommodation (see Table 2-3) [152]. When these dimensions are combined, they are termed ***access***. Of these five dimensions, availability and accessibility are spatial in nature, while the others are largely aspatial. In particular, ***availability*** measures the volume and type of supply, or how many options persons have to choose from when accessing alcohol [152]. It is frequently operationalized as the number of locations in a geographic area and this count can be weighted by a measure of reach (e.g., population, area) [153]. ***Accessibility*** is a measure of the impedance to access the available locations or how long or far a person must travel to access alcohol [152]; thus, these measures often include travel distance or time to specified locations [153]. Affordability measures the price of alcohol, and this could be relative to the person's income and ability to pay [152]. Acceptability is a measure of the alignment between the patron and the seller's actual and idealized notions of the alcohol environment, i.e. is the seller offering an environment that "fits" with the patron's desires for such an environment (thus, patron demographics and seller behaviors can be important variables here) [152]. Accommodation is a measure of how the alcohol outlets are organized to serve patrons (e.g., hours of sale, wheelchair ramps) [152]. Availability and accessibility are related, though they measure distinct aspects of the alcohol environment. In urban settings, it may make sense to measure availability and accessibility simultaneously. Measures of ***spatial access*** do just that [153].

Table 2-3. Key Definitions of Access

Nature of Construct	Dimension of Access	Definition
Spatial	Availability	The options available to a person, often the number of outlets in a location
	Accessibility	The ease with which a person could get to an outlet, often the minimum travel distance or time
Aspatial	Affordability	How much an outlet charges for provided goods or services
	Acceptability	Whether the outlet and the person have congruent idealized notions for how to exchange goods/services
	Accommodation	The functional design of outlets to facilitate patrons

There are three primary methods to measure the alcohol environment: counts, proximity, and spatial access [154]. A measure of availability, counts define "containers" using existing geopolitical boundaries (e.g., CT, ZIP Code) or a user-defined area (e.g., a buffer zone around a point of interest). This method then uses either a raw count or a simple fraction, where the numerator is a count of alcohol outlets and the denominator is a measure of space (i.e., the geographic "container"). Proximity methods are a measure of accessibility, and they summarize the distance from a fixed location (e.g., the participant's home, CT centroids) to the closest alcohol outlet. Lastly, spatial access methods measure availability and accessibility simultaneously by summing the inverse distances from a geographic location (e.g., CT centroids) to a subset of X alcohol outlets (defined by either a set number or a radius). As shown in Figure 2-5, the overwhelming majority (84%) of studies on alcohol outlet access use count methods.

Figure 2-5. Methods Used in Alcohol Outlet Availability Research



NOTE: Based on table presented by Holmes et al. (2014) and updated to include more research since April 2014. If a study compared two or more methods, then the most advanced method was coded.

Within the count method, researchers often use a denominator as a measure of space. Table 2-4 below summarizes the common denominators and their strengths and limitations. However, Schonlau argues that all weights may be inappropriate, because individuals – not populations – experience alcohol outlet access [155].

Table 2-4. Overview of Count-Based Denominators

Denominator	Measures	Strengths	Limitations
Population	Per capita alcohol outlet availability	Most common approach	This is sensitive to population changes; thus, if the number of alcohol outlets in an area is stable but the population increases, it can artificially appear as if alcohol availability is decreased [156]
			This assumes that only residents of the container comprise the at-risk population, ignoring those who may pass through, work in, or patronize businesses in the area under study [94, 157, 158]
Roadway Miles	Spatial availability of alcohol outlets	Alcohol outlets are confined to roads [66, 159]	Census tracts and census block groups are designed to be of similar size and population, not of similar roadway miles [94, 158]
			Patrons can access alcohol outlets by other modes of transportation [158]
Area	Spatial availability of alcohol outlets	Insensitive to population changes over time, which can be beneficial when measuring changes over time [156].	The alcohol outlet availability will be inversely related to the container size, so researchers must be judicious when defining containers
			Insensitivity to population size means these methods cannot detect the population impact of alcohol outlet availability

Table 2-5. Overview of Methods to Calculate Alcohol Outlet Access

Method	Definition	Measures	Strengths	Weaknesses
Count-Based	"Containers" are existing geopolitical boundaries or a user-defined area; count-based methods use either the raw count of alcohol outlets in the container or a simple fraction, where the numerator is a count of alcohol outlets and the denominator is a measure of space: $\frac{C}{w}$ Where: C = count of outlets w = weight	Availability	Easiest to calculate [154]	They do not measure any dimension of accessibility
			Permit comparisons across communities [154]	They assume alcohol outlets are uniformly distributed across the container, which means they are ill equipped to study outcomes where clustering is important [160] or study heterogeneous areas [55, 86, 161]
			Do not rely on a container centroid, which can introduce an additional source of uncertainty [162]	They can overestimate effects [163, 164]
				They are prone to edge effects
				The containers themselves may be poorly designed for spatial analyses (e.g., awkward shape or impractical scale) [90], which can lead to the modifiable areal unit problem [153, 165]
Distance-Based	Travel impedance (e.g., distance, time) from a fixed location: min(d) Where: d = distance to the closest outlet	Accessibility	Avoid edge effects within the study area borders	Studies of the closest alcohol outlet in urban areas are insensitive to the reality that there are often many alcohol outlets at similar distances [153]
			Proximity to the nearest outlet is anticipated to be a better measure of access for rural areas, where residents are more likely to patronize the closest outlet [153]	May be biased to weight distance differently depending on whether people live near the centroid or the border [166]
				Unable to adjust for outlet size or detect clustering of outlets, which can increase the effect of the outlet on related harms [158]
Spatial Access	Sum of the inverse distances from a geographic locale on (e.g., CT centroids) to a subset of X alcohol outlets, often calculated as: $\sum_{1}^{n} \frac{s}{d}$ Where: N = the number of outlets in the choice set D = distance to the outlet S = Supply in the area	Availability & accessibility	Avoid edge effects if use a choice set instead of a boundary	Most difficult to calculate [154]
				Will encounter edge effects if use a radius/buffer
			Research in other fields concludes that spatial access measures are the most robust [153, 167]	Researchers may encounter aggregation bias if the radius selected is too large, because the measure will average across heterogeneous areas [168]
			Inverse distance weighting is a common approach in spatial statistics, and researchers no longer need to aggregate information	If the measure does not use inverse distance weighting (e.g., uses the mean or median distance), it will overweight outlets toward the periphery of the container and will invite edge effects [110]

As the majority of studies use counts, several researchers have compared denominators to determine optimal metrics. Generally, these studies find that the different denominators reached similar conclusions [55, 83, 87]. One lone exception is Romley, Cohen, Ringel, & Sturm (2007), who compared population and roadway mile denominators and found larger effects with the roadway miles measure [159]. In this study on the distribution of alcohol outlets by neighborhood characteristics, the inference depended on the denominator [159]. Blacks, Hispanics, and Asian/Pacific Islanders had greater exposure to bars using the roadway mile denominator (5.44, 6.55, 9.00 and 4.99, respectively) and Whites had greater exposure to bars using the population denominator (1.60, 1.50, 1.60, and 1.91, respectively) [159]. The same was true for socioeconomic status; low-income ZIP Codes had higher bar density than high-income ZIP Codes (7.52 vs. 6.20) using the roadway mile denominator, but high-income ZIP Codes had greater alcohol outlet density using the population denominator [159]. Ultimately, the authors argued that these measures were sensitive to population density. The two measures both generated the finding that Whites had higher bar exposure than non-Whites (except non-White youth) when they restricted to the top two thirds of population density [159]. Thus, it is possible that the most appropriate methods depend on the demographics of the study catchment area [158].

In contrast, relatively few alcohol outlet access studies have compared the three methods in a regression setting. A few studies compared count and proximity measures [115, 169-171], but there are no clear trends from these studies.[1] Grubesic et al. (2016) compared counts and spatial access methods using kappa statistics to determine whether these summary measures captured the same thing [158]. They concluded that the count and spatial access methods measure separate constructs, and the spatial access methods are more sensitive [158].

It would be inappropriate to conclude a discussion of measuring the alcohol environment without discussing the construct of ***alcohol outlet density***. Though the majority of the field deems the subject of their studies "alcohol outlet density" [11, 12, 14, 56, 58, 76, 81-86, 88, 92-95, 97, 105, 108, 109, 121, 127-130, 145, 155, 157, 170, 172-183], only two studies to date faithfully measure that construct [96, 184]. In this context, density refers to locations where outlets concentrate. As such, measuring alcohol outlet density requires the use of distance-based or spatial access methods to detect areas where outlets cluster or the use of formal cluster detection techniques.

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[1] Hay et al. (2009) and Badland et al. (2016) did not find any differences [45]. Kavanagh et al. (2011) found an effect for the count but not proximity methods [138], and Milam et al (2013) found an effect for proximity but not count methods [95].

Fundamentally, counts cannot measure density, because they do not include any measure of the distance to, from, or between outlets.

Data Analysis Techniques

Initially, studies in alcohol outlet availability used OLS regression [42, 55, 75]. However, OLS regression assumes that the regression errors are independent, both over time and space. Around 2000, researchers began to conclude that adjacent areas tended to have similar availability of alcohol outlets, and this similarity can bias the standard errors and invite type I errors [62]. To overcome this hurdle, researchers turned to GLS regression [58, 60-62, 65, 79], which can estimate and correct for positive spatial autocorrelation. As the first step in this new analysis technique, researchers often used Moran's Index (Moran's I), which is a global measure of autocorrelation, to determine whether positive spatial dependence will inflate the standard errors. In some instances, the regression covariates explained all of the spatial dependence [83, 99], but more commonly, corrections were warranted [58, 61, 62, 70, 79, 81, 87, 93-96]. If the data contain evidence of positive spatial autocorrelation, researchers often either include lag terms for predictors [58, 70, 76, 78, 79, 81, 86, 91, 93, 94, 132, 185] or errors [61, 65, 87] to account for that dependence. Spatial lag terms for predictors measure the effect of adjacent areas on the problem of study, whereas spatial error terms account for unmeasured spatially-related covariates.

The analyses using GLS regression were all based on a frequentist perspective [58, 60-62, 65, 79, 98, 99, 137]. Briefly, frequentists assume that sampling is repeatable, and repeated sampling will yield constant parameters. This is in contrast to the Bayesian approach, which assumes that data are fixed, but statistical models can always be updated. Bayesian modeling is becoming increasingly common [68, 70, 91, 121, 145], as it allows researchers to properly account for high levels of variability in small geographic areas in order to identify trends more clearly [70].

Lastly, longitudinal studies of alcohol outlet density often use either spatial panel or time series analyses. Spatial panel analyses allow researchers to model georeferenced data over time, and researchers essentially use simplified versions of these models for the cross-sectional analyses that include lag terms for predictors, errors, and/or covariates [186]. Spatial panel analyses require fewer data points than time series analyses; time series designs require at least 10 data points for each parameter [82]. However, time series designs that control for carefully selected covariates provide the greatest level of statistical confidence in assessing causality [187].

Findings

This section outlines the key findings and trends in alcohol outlet access research. This section is organized to present studies by increasing rigor of design, beginning with cross-sectional studies and ending with time series designs.

Cross-Sectional Analyses

While many studies yield uninterpretable results because they implement transformations like the natural log [77, 79, 95, 122, 157] or square root [95, 138] to meet the regression assumptions, several studies have quantified the strength of the association between alcohol outlet availability and violent crime, and most of these studies have found small but consistent effects. Jennings et al. (2014) estimated that each additional alcohol outlet in a Baltimore CT increased violent crime by 2.2% (*IRR*=1.022, *95% CI* 1.015-1.028, $p<0.001$) [137]. Similarly, Britt, Carlin, Toomey, & Wagenaar found that each additional alcohol outlet in a neighborhood adds five violent crimes per every 1,000 residents in Minneapolis [145]. Among the smallest of findings, Zhu, Gorman, & Horel found the alcohol outlet availability would need to quadruple (go from 12 to 48 outlets among 1,191 residents) to increase violent crime by 16% [70].

Among the studies that compared on- and off-premise outlets, most found stronger effects for off-premise [61, 94, 95, 138, 188]. Nearly all of the studies comparing on- and off-premise alcohol outlet densities use an ecological design because changes over time often reduce either on- or off-premise outlet availability. Using data from 199 CTs in Baltimore, Jennings et al. (2014) found that each additional off-premise alcohol outlet increased violent crime by 4.8% (IRR=1.048, 95% CI 1.035, 1.061) while on-premise outlets increased it by 3.1% (IRR=1.031, 95% CI 1.023, 1.044) [137]. Pridemore & Grubesic found stronger effects for off-premise outlet availability (b=0.16, $p<0.001$) than bar (b=0.13, $p<0.01$) and restaurant availability (b=0.12, p=0.02) in Cincinnati [92]. Among the most substantial differences, Grubesic & Pridemore found stronger effects for off-premise availability (b=0.018, p=0.04) than on-premise availability (b=0.003, p=0.07) in Philadelphia assaults [95]. Lastly, Gorman, Zhu, & Horel determined that only off-premise outlets remained significant after adjusting for drug arrests in Houston, TX [61], and Lipton & Gruenewald corroborated this finding with data from Boston [188].

Branas et al. (2009) provides one of the only individual-level analyses to compare associations between on- and off-premise outlets [90]. This study used an innovative case control design with 1,361 individuals (667 cases and 684 controls) from Philadelphia, Pennsylvania in 2004-2006 [90]. Cases were individuals aged 21 years or older who were shot in an assault in Philadelphia, and they used incidence density sampling to match these cases to population-based controls who were at risk of getting shot [90]. After matching, the study team determined the locations of the cases and controls at the time of the shooting (within 30 minutes) to assess alcohol consumption and alcohol outlet spatial access [90]. Regression results showed that people were twice as likely to be shot in a non-fatal assault if they were in an area with high off-premise alcohol outlet access (OR=2.0, 95% CI 1.05, 3.75, $p<0.05$), and the risk climbed to four times for fatal assaults (OR=4.19, 95% CI 0.81, 21.79, $p<0.1$) [90].

Morrison et al. (2016) provide another individual-level case control study of young adults (aged 10 to 24 years) in Philadelphia, PA [77]. Cases included young adults who sought treatment for a gun or non-gun assault at the Children's Hospital of Philadelphia, and the study identified age-matched controls using random digit dialing [77]. In this study, the association between off-premise outlets and assault depended on the time of day. In particular, proximity to beer stores was associated with increased odds of non-gun assault before 1 PM and from 4 PM to 6:59 PM but decreased these odds after 7 PM [77].

Despite the large number of studies finding greater effects for off-premise outlets, some studies have concluded the reverse [65, 79, 86, 121] and other studies did not detect a clear trend [98]. While this might appear to undermine confidence about inference in the association between alcohol outlet availability and violent crime, these aberrant findings can often be explained by weaknesses in the methodological design. While Gruenewald et al. (2006) found that only bar availability modified the association between population density and assault, this could be attributable to using the victim's residential address rather than the assault location [79]. Toomey et al. (2012) failed to detect an association between off-premise outlet availability and total violent crime after finding such effects for total and on-premise outlet availability [121]. This study only found effects between off-premise outlet availability and robbery (0.19, *95% CI* 0.04, 0.35, $p<0.05$) and assault (0.17, *95% CI* 0.03, 0.31, $p<0.05$) [121]. However, the study area contained few off-premise outlets, and consequently, the analysis might have been underpowered to detect effects of these outlets [121]. Cameron, Cochrane, Gordon, & Livingston found that each additional bar/nightclub in a census administration area (CAU) on the North Island of New Zealand adds 5.28 ($p<0.01$) violent crimes per year, each other club adds 0.84 ($p<0.01$) violent crimes, and each off-premise outlet adds 0.71 ($p<0.01$) violent crimes per year [86]. This finding might be attributable to the large unit of analysis [65].

Though the effects are consistently larger for off-premise outlets, on-premise outlets likely also contribute to violent crime. Roncek & Maier's 1991 analysis only investigated the effects of on-premise outlets. This analysis was ahead of its time in the size of the unit of analysis and controlling for autocorrelation [132]. It found that each bar/tavern on a city block in Cincinnati was associated with a 17.4% increase in violent crime [132]. This is a prime example of the spatial relationship between on-premise outlets and violent crime because it uses the smallest unit of analysis to date, which means it assumes that violence will occur between the on-premise outlet and the patrons' car/home.

Longitudinal Analyses

There is a small subset of studies that implement longitudinal methods in the absence of a natural experiment to detect the effects of fluctuations over time [68, 78, 82, 85, 100, 189]. Like the cross-sectional studies, these analyses tend to find small but positive effects. For example, Livingston found that each additional outlet in a Melbourne postcode was associated with 0.25 additional alcohol-related assaults requiring hospitalization each year [82]. Consistent with the cross-sectional findings, this analysis found a stronger association for off-premise outlets ($\beta=0.39$, $p<0.001$) than on-premise outlets ($\beta=0.25$, $p<0.001$) [82].

Two similar studies compared the effects of on- and off-premise densities and concluded that on-premise had stronger effects [68, 78]. Both of these longitudinal studies used hospital-based assault data to evaluate the effects of natural changes in alcohol outlet density over time using ZIP Code data from California [68, 78]. Thus, these analyses are limited both by using the victim's residential location instead of the assault location and a large unit of analysis. Still, these analyses detected associations for on-premise and off-premise outlets and concluded that the association between outlets and assault was stronger for bars than off-premise outlets [68, 78]. Gruenewald et al. concluded that every six bars in a ZIP Code explain one assault, so the 3,500 bars across 581 ZIP Codes in California could produce up to 600 hospital admissions for assault injuries each year [78]. Mair et al.'s primary findings extended from testing statistical interactions [68]. They found that areas with high population density, a high percentage of African American residents, and low median annual household income are particularly vulnerable to the effects of bar density on assault injuries [68].

Natural Experiments

If alcohol outlet access is causally related to violence, then one would expect the rates of violence to rise or fall as alcohol outlet access increases or decreases. Evaluations of natural experiments test this hypothesis. All of the rigorously designed analyses of natural experiments have detected an association between alcohol outlet availability and violent crime [67, 87, 91, 184, 190].[2]

The 1992 Los Angeles riots provide an interesting early natural experiment because many alcohol outlets were burned during the rioting. A recent analysis of these data show reductions in assaultive violence were proportional to the number of alcohol outlets lost in a census tract [87]. Similar results were found for other outcomes, like sexually transmitted infections [112].

In 1997, New Orleans adopted several policies related to the physical availability of alcohol, including an increased license fee, increased enforcement, and expanded authorities for the liquor licensing board with the end goal of reducing problematic alcohol outlet operations [190]. This policy ultimately resulted in fewer alcohol outlets in New Orleans. After controlling for other trends in violent crime, researchers concluded that the reduction in the number of alcohol outlets was associated with fewer violent crimes [190].

Zhang et al. studied the closure of large numbers of on-premise outlet in the Buckhead neighborhood of Atlanta, Georgia in the timeframe between 1997 and 2007 [184]. This is the only natural experiment that used spatial access methods to measure alcohol outlet access and violence exposure and limited the case and control sites to high outlet density census block groups [184]. Using multilevel regression with random effects, the analysis found that violent crime decreased twice as much in the areas that limited alcohol outlet density relative to areas that did not limit alcohol outlet density [184].

Two other studies compared on- and off-premise alcohol outlet density and concluded there was a stronger effect for off-premise outlets [67, 91]. Tabb, Ballester, & Grubesic evaluated the privatization of liquor sales in Seattle, Washington using data from 567 census block groups in 2010 to 2013, and Gorman et al. evaluated ending a ban on off-premise outlets in Lubbock, Texas using data from 172 census block groups in 2006 to 2011. Tabb,

[2] One evaluation of the end of a ban on off-premise sales and subsequent introduction of 77 off-premise outlets in Lubbock, Texas failed to detect an association; however, a more rigorous evaluation four years later detected an association between the increase in off-premise outlets and violent crime.

Ballester, & Grubesic used hierarchical spatio-temporal modeling in a Bayesian framework and found that each additional off-premise outlet increased aggravated assault by 8% and each on-premise outlet increased aggravated assaults by 5% [91]. In contrast, Gorman et al. used spatial Poisson panel modeling and determined that each additional off-premise outlet increased violent crime by 14.6% in the adjacent census block group [67].

Limitations

This body of research has important methodological limitations. Alcohol outlet availability often does not change quickly, which means that time series and natural experiments are rare. Most of the literature uses cross-sectional, ecological designs [11, 165], which alone cannot infer causality. In the context of these designs, one must consider the ecological fallacy that states that findings at the population level might not generalize to the individual level [191, 192]. This is particularly problematic when the associations at the individual level differ within a geographic location, otherwise known as aggregation bias [193].

The choice of units for ecological analyses can also introduce error. Firstly, larger units of analysis often contain a more heterogeneous mix of individuals, which can aggravate aggregation bias. However, units of analysis can also create the modifiable areal unit problem (MAUP), which can bias results when point data are aggregated using containers. MAUP states that results depend on the size and shape of the units used to aggregate the data. This is particularly problematic for analyses that implement a container-based design.

The spatial association between off-premise outlets and related harms may also be difficult to measure. Cameron, Cochrane, Gordon, & Livingston argue that there is a diffusion bias for off-premise outlets such that there is a spatial and temporal lag between point of purchase and consumption for these outlets [86, 182]. In support of this, many studies find significant spatial lag effects [58, 67, 68], showing that the availability of alcohol outlets can drive violent crime in adjacent areas. As the point of the harm extends further away from the point of sale, there is greater opportunity for additional sources of error that might prevent accurate measurement.

The data sources commonly used in alcohol outlet access research also introduce limitations. Liquor license records often do not provide details that would permit researchers to disaggregate outlets more granularly than on- and off-premise. In particular, sales volumes, trading hours, outlet size, the presence of a kitchen, and average price are all key factors that would help researchers isolate the effects different types of outlets [156]. Thus, small upscale restaurants may look the same as sprawling megabars in many datasets and risky liquor stores may look like grocery stores. The theories underlying this literature all hypothesize that the effects of these outlets will depend on how they function, whether arising from the volume of sales or from bringing people together in different settings. Consequently, there currently is insufficient data to conduct a meta-analysis of different types of alcohol outlets [165]. Thus, while the data demonstrate that off-premise outlets have stronger effects on violent crime, it is still unclear what specific types of off-premise outlets are the most problematic [165].

Lastly, studies that attempt to combine individual survey data with alcohol outlet data are often confronted with low geographical resolution (e.g., ZIP Code) to protect patient confidentiality [178, 194, 195]. This undermines the researchers' ability to make inferences, because ZIP Codes are often heterogeneous and not designed to be comparable in terms of population or area.

Conclusions and Directions for Future Research

In conclusion, the available evidence linking alcohol outlet availability to related harms consistently finds positive effects, particularly for violent crime. This research has important policy implications, as it is an upstream determinant that likely shapes individual-level behavior, like drinking and committing violent acts. However, researchers must consider methodological rigor. There have been two recent calls to action for researchers to pay greater attention to the methods underlying this field [69, 165]. In response, the Centers for Disease Control and Prevention (CDC) [156] and others [158] have argued for replacing the popular yet crude count-based availability methods with more rigorous spatial access designs. However, this recommendation has not yet been empirically tested in a regression setting, and the field has not yet begun to operationalize this guidance. Chapter 3 addresses this gap by comparing count, proximity, and spatial access methods in a regression setting to determine which method yields the most stable and precise measure of alcohol outlet access. Chapter 4 then extends this work by using the method identified in chapter 3 to determine the association between alcohol outlet access and violent crime in Baltimore City, Maryland.

As there are often legal processes and guidelines that determine the number and location of alcohol outlets in an area, this body of research has important policy ramifications. However, there is often a translation gap, whereby the results of alcohol outlet availability studies cannot directly inform policy recommendations. Holmes et al. provide a detailed example of this translation gap, detailing the experience of liquor licensing in the United Kingdom (UK) [69]. In the UK, policymakers attempted to enact evidence-based zoning decisions, but ultimately couldn't link routinely collected data on harms to specific outlets or groups of outlets [69]. This is further complicated by the reality that the number and types of alcohol outlets that a community can handle is likely context-specific. While there is no set ideal number of outlets per 1,000 residents, the data demonstrate that there is a threshold effect where related harms increase exponentially after a certain saturation point [83]. To date, there is only one prospective analysis that models the anticipated effects of alcohol outlet zoning policies on binge drinking in New York [196]. Future research should continue to expand this body of research to help policymakers utilize this evidence to prevent health harms. Chapter 5 addresses this translation gap by presenting a cost-effectiveness analysis that models the number of violent crimes that could be prevented under four different alcohol outlet zoning policies.

Chapter 3: Methods for Measuring the Association between Alcohol Outlet Access and Violent Crime

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Abstract

Background: There has been a recent proliferation of studies connecting alcohol outlet access to violent crimes. Most of these studies measure alcohol outlet access and violent crime using counts of a geographic area even though this method may miss important information about how the alcohol outlets and crimes are distributed within these areas. The objective of the current analysis was to compare and test the statistical rigor of multiple measurement methods – counts, proximity and spatial access methods – of calculating alcohol outlet access and exposure to violent crimes using a single, city-based dataset.

Methods: A total of 32 models were tested. Negative binomial regression was used for count outcomes and linear regression for proximity and spatial access outcomes. Choropleth maps and Akaike's Information Criterion (AIC) guided determination of which model yielded the best fit for the data.

Results: Greater alcohol outlet access was consistently associated with more violent crime, though the strength of the association depended on the measurement method used. Count methods largely failed at explaining geographic variation. Proximity explained much of the variation but yielded somewhat unstable estimates of outlet access. Using spatial access methods with a choice set for both alcohol outlets and violent crimes yielded the most stable estimates with highest precision.

Conclusion: The method chosen for measurement of alcohol outlet access and violent crime is critical to the accuracy of the results. Using spatial access methods for both independent and dependent variables, with a choice set for each, is most likely to yield the most stable and precise results.

Background

Since 2000, there has been a surge of research connecting alcohol outlets with related harms, particularly violence [67, 68, 79, 82, 83, 87, 88, 90, 93, 98, 121, 137, 184, 190, 197]. However, there are conflicting findings. For example, it is unclear whether on-premise (e.g., bars, restaurants) [65, 79, 82, 121] or off-premise outlets (e.g., liquor stores) [61, 81, 82, 90, 99, 122, 198] are associated with greater levels of harms. Other studies conclude that it could be the time of day and day of the week that determines the outcomes of each type of outlet [199]. There is also disagreement about whether alcohol consumption mediates the association between alcohol outlet access and related harms, where some findings conclude there is [174] and others conclude there is not [178, 194]. These disagreements could purely be an artifact of poor measurement. Today, researchers often measure alcohol outlet access using the same methods as the first studies linking the location of alcohol outlets with related harms [31, 40-42, 53-55, 63, 75]: they count the number of alcohol outlets located in a geographic area [67, 71, 74, 86, 91, 122, 137, 138]. In response to this and other related issues, researchers recently challenged the field to use more rigorous methods [69, 165] and provided guidance on the strengths and weaknesses of common methods [154]. The Centers for Disease Control and Prevention (CDC) published this guidance in June 2017 to highlight the advantages and disadvantages of three of the most common methods of calculating alcohol outlet access. Providing statistical evidence about the performance of these techniques fell outside of CDC's scope. This paper offers conceptual and statistical evidence on the relative advantages and disadvantages of different methods for quantifying alcohol outlet access and violence.

As a conceptual foundation, this paper draws on Penchansky & Thomas's seminal article on the types of access. They propose five dimensions that describe the degree of fit between a person and their environment: availability, accessibility, affordability, acceptability, and accommodation [152]. The combination of these five dimensions comprise ***access***. Of these five dimensions, only availability and accessibility are spatial. ***Availability*** measures the volume and type of supply, or how many options persons have to choose from when accessing alcohol [152]. ***Accessibility*** is a measure of the impedance to access the available locations, or how long or far a person must travel to access alcohol [152]. Availability and accessibility are related, though they measure distinct aspects of the alcohol environment. The non-spatial dimensions of access are affordability, acceptability, and accommodation. Affordability measures the price of alcohol, and this could be relative to the person's income and ability to pay [152]. Acceptability is a measure of the alignment between the patron and the seller's actual and idealized notions of the alcohol environment (e.g., patron demographics, seller behaviors) [152]. Accommodation is a measure of how the alcohol outlets are organized to serve patrons (e.g., hours of sale, wheelchair ramps) [152].

Three of the most common methods for calculating alcohol outlet access can be categorized as count, proximity, and spatial access methods. Counts begin by defining a "container" using existing geopolitical boundaries (e.g., census tract, ZIP Code) or a user-defined area (e.g., a buffer zone around a respondent's house). This method then sums the number of outlets located inside the "container" and often weights the count by a measure of space (e.g., population, square miles). Proximity methods measure the distance between a specified location (e.g., census block group centroid, participant's house) and the closest alcohol outlet. Spatial access methods are the most complex of the three measurement approaches; these methods combine counts with distances. Commonly, this method calculates a spatial access index for a set of alcohol outlets. The set of alcohol outlets may be defined using a given number (e.g., seven outlets) or a "container" (e.g., a 0.5-mile buffer around a census block group centroid). The distance to each of the outlets may use either standard or inverse distance. For example, a common spatial access method is to calculate a spatial access index (SAI) that sums the inverse distances from a census block group centroid to the seven closest alcohol outlets [184].

These three measurement categories map directly to the Penchansky & Thomas framework. Counts capture availability – the number of options a person has to purchase alcohol outlets in a given area [153]. Proximity measures accessibility – how easy it is for a person to get to the nearest alcohol outlet [153]. Spatial access methods simultaneously measure availability and accessibility [153].

Understanding how these three methods relate to the Penchansky and Thomas framework reveals an obvious conceptual limitation of both count and proximity methods: these approaches only measure one of the two spatial dimensions of the alcohol environment. Numerous studies demonstrate that alcohol outlet availability [14, 67, 78, 79, 81-83, 98, 99, 121, 137] and accessibility [136, 200] are both important determinants of violence. This means that spatial access methods offer a conceptual advantage by capturing the full spatial dimension of alcohol outlet access.

In addition to the conceptual strengths and weaknesses, one must also consider methodological rigor when selecting a measurement method. Counts are the most common method used [69]. They are among the easiest to calculate, do not require street-level data, are intuitive to understand, and permit comparisons across communities.

However, counts treat alcohol outlets as if they are uniformly distributed throughout the “container,” which means these methods may miss important information about whether the alcohol outlets cluster together. This inability to detect clustering is a profound limitation in alcohol outlet access research, because clustering of alcohol outlets fuels violence [96, 160]. Further, all container-based methods run the risk of introducing aggregation biases if they average effects over large, heterogenous populations [69]. The results of container-based methods will depend on the size and shape of the container used, which is a challenge known as the “modifiable areal unit problem” [165]. Lastly, container-based methods are also prone to edge effects, which means that alcohol outlets across a container boundary may influence the outcome inside the container.

Proximity methods avoid some of the methodological limitations of counts. These methods do not use “containers,” so they avoid aggregation bias, the modifiable areal unit problem, and edge effects. In addition, these methods only require data from two locations: the reference point and the nearest alcohol outlet. This is simultaneously a strength and a weakness. It is a strength because it means that proximity methods are easy to calculate. Conversely, it is also a weakness because relying on the alcohol outlet nearest to an often randomly-chosen reference point is a somewhat random process. This means that proximity methods are anticipated to be the least stable.

Spatial access methods offer several distinct methodological strengths. The primary advantage is that these methods can detect clustering. In addition, spatial access methods that use a “choice set” approach (i.e., the distance/inverse distance to the N nearest alcohol outlets, with the choice set being those outlets) produce smoothed estimates, meaning that they draw information from surrounding areas to estimate access of areas with few outlets. Smoothing can help yield stable estimates in locations with few data points without requiring researchers to aggregate to larger units [162]. However, spatial access methods are the most difficult to calculate, and the results may be difficult to interpret. In addition, results from methods that determine proximity to centroids can be sensitive to whether the calculations are performed using the centroid, centers, capitals, or some other point [162].

Groff (2013) was the first to compare spatial access and count methods [201]. Groff’s analysis compared three methods: 1) A count of the number of outlets, 2) An inverse distance weight (IDW) count, and 3) A distance-weighted activity (DWA) measure [201]. The IDW count summed the inverse distances from a street block centroid to all alcohol outlets and the DWA measure multiplied the total alcohol sales by the IDW count [201]. Using street block-level data, Groff calculated these three variables using three buffer sizes: 800 feet, 1,200 feet, and 2,800 feet [201]. She concluded that the IDW count provided the best fitting models, using Akaike's information criterion and adjusted R-squared values, though the simple count performed similarly to the IDW count [201]. Groff concluded that the sales component of the DWA measure captured a different dimension than the first two measures [201].

Recently, Grubesic, Wei, Miller, & Pridemore compared several gravity models -- a spatial access method that measures the interaction between two objects, in this case alcohol outlets and census tracts -- to count methods. They concluded that spatial access methods were more sensitive [158]. However, the analyses only tested container-based spatial access methods, and they did not compare the performance of the methods in a regression setting. The objective of the present study is to compare count, proximity, and spatial access methods for measuring the association between alcohol outlet access and violent crime in a regression setting using one dataset. The study hypothesizes that spatial access methods will provide the most precise fit to the data when compared to the other two methods.

Methods

Background

Setting

With a 2017 population of 614,00 residents, Baltimore is the largest city in Maryland and the 29th largest city in the United States [202]. In 2016, Baltimore had 1,780 violent crimes per 100,000 residents, which is similar to Detroit, Michigan (2,046), Saint Louis, Missouri (1,903), and Memphis, Tennessee (1,820) [203]. Baltimore is a city of neighborhoods, and many of the neighborhoods are comprised of tightly packed row houses. In such a setting, greater density could amplify influences of spatial factors.

Geographic Units

To minimize aggregation bias, census block groups (CBGs) were the primary geographical unit of analysis in this study. CBGs in Baltimore contain between 0 and 4,828 people, and there are on average three CBGs per census tract. There are 653 CBGs in Baltimore. Fifty-four CBGs (8.3%) were missing income data (three were largely industrial areas with a population of 0, and the ACS suppressed the values for the remaining 51 CBGs), so the final sample size comprised 599 CBGs.

Data Sources

Baltimore City Liquor License Commissioners

Liquor license information, including license type and address, was obtained for 1,218 alcohol outlets from the Board of Liquor License Commissioners for 2016. Liquor license information was current as of July 4, 2016. Fourteen (1.1%) license types with a range of restrictions on days/hours of sales and types of products that may be sold were excluded including (arenas [7], municipal [5], Pimlico Race Track [1], and Baltimore Zoo [1]). The addresses for the remaining 1,204 outlets were geocoded using an address locator in ArcGIS and StreetMap 2013. Researchers were able to geocode 100% of the outlets.

Baltimore City Police Department

Victim-based violent crime and drug arrest data were obtained from the Baltimore City Police Department (BCPD), including type of crime/arrest and location [204]. Violent crimes included homicide, aggravated assault (including non-fatal shootings), rape, and robbery and crimes that involve force or the threat of force [205]. These crimes were selected because police reports of serious crimes such as these are reliable indicators of the real crime rate [206]. From 2012-2016, there were 51,006 violent crimes (1,322 homicides [2.6%], 1,410 rapes [2.8%], 22,267 robberies [43.7%], and 26,007 aggravated assaults [51.0%]). The BCPD publish these data monthly and provide approximate coordinates for each crime location. The dataset was current as of January 3, 2018. BCPD excludes crimes for which they were unable to geocode the incident location; the proportion of crimes that BCPD was able to geocode is unknown. This analysis was able to geocode 7,854 (98%) of the 8,032 drug arrests in 2016.

American Community Survey

The American Community Survey (ACS) is an annual national survey that collects vital household information from nearly 2 million addresses each year. Public Use Microdata Sample (PUMS) files provide datasets for academic use in 1-year, 3-year, and 5-year files; the analysis used the dataset with five-year estimates (2012-2016), as it provides information for areas as small as CBGs [207]. Data for the demographic covariates (percent African American, count of vacant housing, median annual household income, population density, and percent of population aged 18-35 years) came from the ACS.

Measures

Alcohol Outlet Access Variables

To compare methods for measuring alcohol outlet access, we calculated alcohol outlet access using three separate methods: count, proximity, and spatial access.

Counts. This study used the spatial join tool in ArcGIS to count the number of alcohol outlets located in each CBG. Four versions of this variable were then calculated using different denominators: no denominator, population, area (measured in square miles), and roadway miles. These are the most common approaches used in the field [69].

Proximity. The closest facility function in the network analyst ArcGIS toolbox was utilized to calculate the proximity variable. In particular, we determined the shortest network distance (i.e. distance using existing roadways) from each CBG centroid to the closest alcohol outlet.

Spatial Access. Spatial access variables were also created using the closest facility tool to calculate the network distance from each CBG centroid to the alcohol outlets. We created three spatial access variables: a spatial access index (SAI) that summed the inverse distance to a defined "choice set" of alcohol outlets, a SAI that summed the inverse distance to all alcohol outlets located inside a 0.5-mile buffer from the CBG centroid, and the mean distance for the choice set of alcohol outlets. SAIs were calculated by summing the inverse distance to a set of alcohol outlets (an IDW count), defined as $\sum_1^N \frac{1}{d}$ where *N* is the number of outlets and *d* is the distance to each outlet. The use of inverse distance gives outlets that are located closer to the reference point a higher weight; in other words, the IDW count provides the number of alcohol outlets in an area, discounting for distance [201]. Thus, larger values of the SAI indicate greater alcohol outlet access. The size of the choice set was determined using literature about consumption decision making. Consumers consider up to seven plus or minus two options when making choices or evaluating settings, and cognitive studies have been applied to decisions in analysis of access to parks, shopping locations, alcohol outlets, and others (see Zhang, Lu, & Holt, 2011, for discussion) [184, 185, 208]. Thus, "choice sets" comprised seven outlets in this study. For the SAI variable that uses a buffer, the 0.5-mile radius around the CBG centroid was selected because this approximately represents a 10-15 minute walk, which is the maximum walking distance for many people [209].

Violent Crime Variables

The analysis also calculated violent crime using three separate methods.

Counts. This study used the spatial join tool in ArcGIS to count the number of violent crimes in each CBG from 2012-2016. The count violent crime variable is a crude count; the analysis did not weight the count using a denominator.

Proximity. The proximity to violent crime variable was calculated using the same methods as the proximity for alcohol outlets.

Spatial Access. This analysis calculated the spatial access of violent crime variable using a SAI for a defined choice set of violent crimes and a SAI for a defined buffer area around the CBG centroid. The analysis used seven violent crimes for the choice set approach and a 0.25-mile buffer to measure for violence in order to capture local effects.

Control Variables

We controlled for higher levels of density of outlets by defining high-density clusters, because the association between alcohol outlet access and violent crime may differ in high-density areas. Seventy-nine percent of alcohol outlets were located less than 0.1 miles from the nearest alcohol outlet, and 88% were located with 0.15 miles. Thus, we compared a 0.1-mile and a 0.15-mile buffer to identify high-density areas. The analysis created and merged buffers around each alcohol outlet. Sets of overlapping buffers that corresponded to 50 or more alcohol outlets were defined as high-density clusters. Ultimately, the 0.1-mile buffer provided a more precise fit without substantial overlap, identifying 102 CBGs (15.6%) as high-density areas. The 0.15-mile buffer identified nearly half of the city (302 CBGs, 46%) as high-density areas. Thus, we proceeded with the 0.1-mile buffer. A spatial join was used to identify the CBGs that contained high-density areas, and a binary variable was created to identify these high-density CBGs. The analysis also tested an interaction term between the alcohol outlet access and high-density variables to determine if the association between alcohol outlet access and violent crime differed in low- and high-density areas.

All multiple regressions controlled for demographic covariates selected using social disorganization theory [133, 139, 140]. Covariates included count of drug arrests in 2016 (as a measure of disorganization), percent African American, count of vacant housing, median annual household income, population density, and percent of population aged 18-35 years. Collinearity between the covariates was not a problem, as all variance inflation factors were less than two. The covariates were scaled to aid interpretation, so a one-unit increase represented a 10% increase in percent African American and percent aged 18-35 years, 100 houses for count of vacant housing, and $10,000 for median annual household income. Drug arrest data were geocoded in ArcGIS. The count of drug arrests was log transformed to adjust for positive skew.

Statistical Analysis

Preliminary analyses were conducted using Stata version 14, and p-values less than 0.05 were considered statistically significant. The analysis natural log-transformed the measures of alcohol outlet access to reduce the positive skew and to mitigate the influence of outliers. Count methods added 0.0001 to the variables before applying the natural log transformation because there were CBGs with no outlets. The rest of the statistical analyses depended on the type of dependent variable, and a total of 32 models were tested. These models are summarized in Table 3-1 below.

Table 3-1. Overview of the 32 Models, Listed by Model Number

			Violent Crime			
			Count	**Proximity**	**Spatial Access**	
			Raw Count	**Distance to Nearest Crime[a]**	**SAI with 7 nearest crimes[b]**	**SAI with 0.25-mile buffer[c]**
Alcohol Outlets	Count	Raw count	#1	#9	#17	#25
		Count weighted by population	#2	#10	#18	#26
		Count weighted by area	#3	#11	#19	#27
		Count weighted by roadway miles	#4	#12	#20	#28
	Proximity	Distance to nearest outlet[d]	#5	#13	#21	#29
	Spatial Access	SAI with 7 nearest outlets[e]	#6	#14	#22	#30
		SAI with 0.5-mile buffer[f]	#7	#15	#23	#31
		Mean distance to 7 nearest outlets[g]	#8	#16	#24	#32

SAI Spatial accessibility index
[a]Calculated as the minimum distance from the census block group centroid to the closest violent crime.
[b]Calculated by summing the inverse distances from the census block group centroid to each of the seven closest violent crimes.
[c]Calculated by summing the inverse distance from the census block group centroid to each violent crime located within a 0.25-mile buffer.
[d]Calculated as the minimum distance from the census block group centroid to the closest alcohol outlet.
[e]Calculated by summing the inverse distances from the census block group centroid to each of the seven closest alcohol outlets.
[f]Calculated by summing the inverse distance from the census block group centroid to each alcohol outlet located within a 0.25-mile buffer.
[g]Calculated as the average distance from the census block group centroid to the seven closest alcohol outlets.

Count Outcomes

Negative binomial regression was used for models 1-8. Deviance goodness of fit analyses confirmed that Poisson regression provided an inappropriate fit to the data for model 1 (χ^2=1.1e+04, p<0.001), model 2

(χ^2=1.1e+04, p<0.001), model 3 (χ^2=1.1e+04, p<0.001), model 4 (χ^2=1.1e+04, p<0.001), model 5 (χ^2=9,190, p<0.001), model 6 (χ^2=8,602, p<0.001), model 7 (χ^2=1.1e+04, p<0.001), and model 8 (χ^2=1.1e+04, p<0.001). The negative binomial regressions used the natural log of the 2016 population as the offset.

Proximity & Spatial Access Outcomes

Linear regression was used for models 9-32. Both the dependent and independent variables are log-transformed in these models, so the regression coefficients can be interpreted as elasticities.

Spatial Analyses

All spatial analyses were performed in R. Moran's Index (Moran's I) was calculated on the measures of violent crime and regression standardized residuals using a first order Queen adjacency matrix requiring at least two adjacent sides to determine spatial dependence. A Monte Carlo estimation process was used for the distance-based and spatial access measurements. The violent crime variables all contained positive spatial autocorrelation (Moran's I ranged from 0.23 to 0.32, all p<0.001), indicating that observations were not independent. Among the independent variables, proximity to the nearest crime (Moran's I 0.84, p<0.001) and the average distance to the seven nearest crimes (Moran's I 0.82, p<0.001) contained the greatest amount of spatial autocorrelation. The initial regressions accounted for more than 50% of the spatial dependence (count of violent crime Moran's I 0.12-0.15, p<0.001; proximity to violent crime Moran's I 0.05-0.06, p<0.05; SAI for seven nearest crimes Moran's I 0.05-0.07, p<0.05; SAI for crimes in 0.25-mile buffer Moran's I -0.01-0.01, p>0.05). While the Moran's I for models 1-24 are still statistically significant, a Moran's I of 0.05-0.15 is small. In addition, the negative binomial regression accounts for overdispersion. Lastly, the effects in the main regression models are highly significant (largest p value was p=0.005), so it is unlikely that adjusting for the remaining spatial dependence would change the inference. In combination, these circumstances mean the unadjusted models should be approximately accurate. Still, running spatial lag models, and adding lag terms for the alcohol outlet access variables and/or covariates, did not account for any additional spatial dependence.

Results

Descriptive statistics are presented in Table 3-2. On average, CBGs were 0.11 square miles (range: 0.02–1.01 square miles) and contained 983 residents (range: 141–3,828 residents). Percent African American had a bimodal distribution (mean 66%, range 0–100%), suggesting trends of racial segregation. Median annual household income, drug arrests count, and vacant houses count were all right skewed. The median annual household income was $41,406 (range: $8,281-$250,000), and the average CBG had 12 drug arrests (range: 0 – 183 arrests) and 85 vacant homes (range: 0–377 vacant homes). Percent of the population aged 18-35 years was fairly symmetrical (range 3-95%, mean 32%).

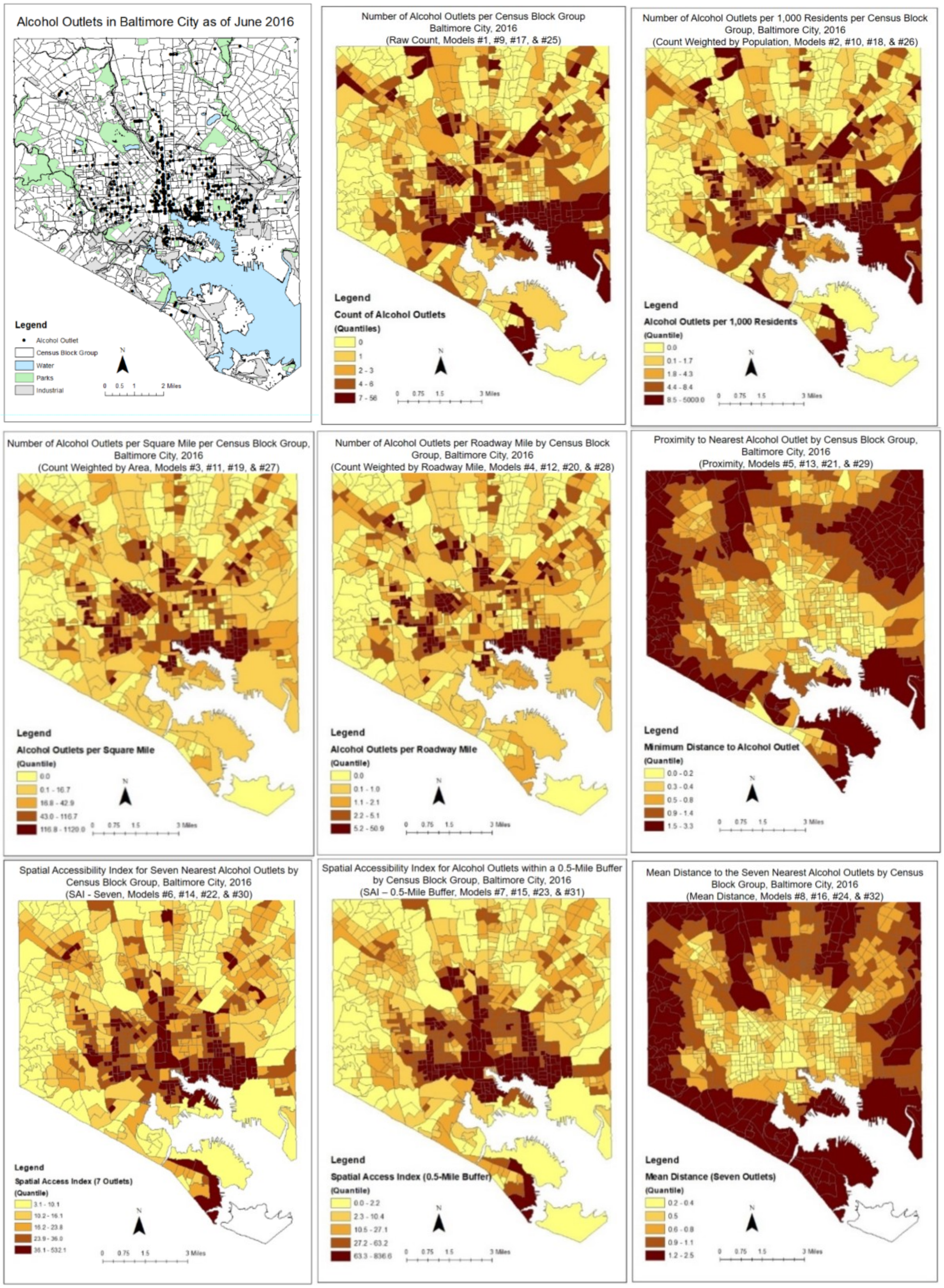
Table 3-2. Descriptive Characteristics of Census Block Groups, Baltimore City, 2016 (n=599)

Variable	Mean	SD	Min	Max
Total population	983	500	141	3,828
Total area (square miles)	0.11	0.12	0.02	1.01
Total roadway miles	1.94	1.65	0.22	16.07
Count of drug arrests	12	18	0	183
Percent African American	67%	35%	0%	100%
Count vacant houses	85	68	0	377
Median annual household income[a]	$47,786	$29,056	$8,281	$250,000
Percent of population aged 18-34 years	32%	14%	3%	95%
Count of violent crime[b]	78	78	2	1,215
Minimum distance to violent crime[c]	0.05	0.07	<0.01	0.77
SAI of violent crime – seven[d]	7,190.83	164,169.20	4.24	4,190,382.00
SAI of violent crime – 0.25 mi[e]	8,542.76	171,417.50	0.00	7,191,265.00
Count of alcohol outlets	4	6	0	56
Outlets per 1,000 residents	4.39	6.32	0.00	51.19
Outlets per square mile	69.24	134.63	0.00	1,120.00
Outlets per roadway mile	2.91	5.20	0.00	50.92
Proximity (miles)[f]	0.30	0.27	<0.01	1.91
SAI for seven nearest outlets[g]	27.35	33.42	3.09	532.09
SAI with 0.5-mile buffer[h]	44.01	78.08	0.00	836.63
Mean distance to seven nearest outlets[i]	0.51	0.35	0.04	2.30

SD=standard deviation; Min=minimum; Max=maximum; SAI=spatial accessibility index
[a]Median annual household incomes greater than $250,000 are censored.
[b]Violent crime data are from 2012-2016.
[c]Calculated as the minimum distance from the census block group centroid to the closest violent crime.
[d]Calculated by summing the inverse distances from the census block group centroid to each of the seven closest violent crimes.
[e]Calculated by summing the inverse distance from the census block group centroid to each violent crime located within a 0.25-mile buffer.
[f]Calculated as the minimum distance from the census block group centroid to the closest alcohol outlet.
[g]Calculated by summing the inverse distances from the census block group centroid to each of the seven closest alcohol outlets.
[h]Calculated by summing the inverse distance from the census block group centroid to each alcohol outlet located within a 0.5-mile buffer.
[i]Calculated as the average distance from the census block group centroid to the seven closest alcohol outlets.

On average, there were 78 violent crimes per CBG and the distance from the CBG to the nearest violent crime was 0.05 miles (264 feet). The SAI for the seven nearest crimes was highly right skewed; it ranged from 4.24 to 4,190,382.00. Though 99% of the SAIs for the seven nearest crimes were less than 6,394.97, these SAIs were skewed and the high values pulled the average SAI to 7,190.83. The SAI using a 0.25-mile buffer was also heavily right skewed; the average SAI (8,008.81) fell between the 95th (3,903.78) and 99th percentiles (8,373.15).

Figure 3-1. Distribution of Alcohol Outlets and Alcohol Outlet Access Variables



Baltimore CBGs contain between 0 and 56 outlets with an average of four outlets in each CBG. The distribution of the count of outlets was right skewed, meaning that many CBGs had no or low counts of alcohol outlets. On average, CBGs contain four alcohol outlets per 1,000 residents, 69 outlets per square mile, and three outlets per roadway mile. The average distance to the nearest outlet was 0.30 miles (1,584 feet). The two SAIs were both right skewed. The average SAI using the seven nearest alcohol outlets was 27.35 (range: 3.09 to 532.09), and the average SAI using a 0.5-mile buffer was 44.01 (range: 0.00 to 836.63). The average mean distance to the seven nearest alcohol outlets was 0.51 miles (2,693 feet).

Figure 3-1 shows the geographic distribution of the alcohol outlets and the alcohol outlet access variables across Baltimore for 2016. Outlets tend to cluster in the city center (downtown) and adjacent to the Inner Harbor (which is an entertainment area) as well as roughly two miles east and west from the city center. The summary measures of alcohol outlet access tended to follow this pattern. Compared to the other methods, the counts using an area-based or roadway miles denominator had relatively lower levels for downtown, as these are above-average sized CBGs (0.15 and 0.32 square miles) with more businesses but fewer residences. All methods appear to capture the clusters in east and west Baltimore, though the clusters tend to be smallest with the count variables and largest with the spatial access methods using the choice set (i.e., the SAI using the seven nearest alcohol outlets and the mean distance to the seven nearest alcohol outlets). The methods produce conflicting estimates of the level of alcohol access in the larger CBGs in far east and far south Baltimore. The counts with no denominator or a population denominator categorize these areas as high availability, while the proximity and spatial access methods categorize them as low access.

The results of the regressions are presented in Table 3-3. There is a consistent positive association between alcohol outlet access and violent crime across all models (note the direction for the minimum distance and mean distance methods are reversed, as larger distances mean lower access). Models that used a proximity or spatial access approach to measure alcohol outlet access yielded greater levels of significance than count models, regardless of the method used to measure violent crime. However, the count alcohol outlet variables yielded highly significant findings when violent crime was also measured using a count variable (models 1-4 *IRR*=1.03-1.04, $p<0.001$). In addition, combining counts with the SAI for the seven nearest crimes yielded highly significant results in models 18 (β =0.04, $p<0.001$) and 19 (β=0.03, $p<0.001$). The models with counts of alcohol outlets and proximity to violent crime (models 9-13 β=-0.03 to -0.04, p<0.01) and the SAI with a buffer (models 25-27, β=0.07 to 0.08, p<0.01) had less significant results. In contrast, the proximity to the nearest alcohol outlet was highly significant, regardless of how violent crime was measured (model 5 *IRR*=0.77, p<0.00; model 13 β=0.33, p<0.001; model 21 β=-0.33, p<0.001; model 29 β=-0.94, p<0.001). The three spatial access methods of alcohol outlet access also showed a similar association with the SAI using the seven nearest alcohol outlets (model 6 *IRR*=1.53, <0.001; model 14 β=-0.47, p<0.001; model 22 β=0.45, p<0.001; model 30 β=1.37, p<0.001), the SAI using a 0.25-mile buffer (model 7 *IRR*=1.06, p<0.001; model 15 β=-0.07, p<0.001; model 23 β=-0.06, p<0.001; model 31 β=0.22, p<0.001), and the average distance to the seven closest alcohol outlets (model 8 *IRR*=0.60, p<0.001; model 16 β=0.48, p<0.001; model 24 β=-0.47, p<0.001; model 32 β=-1.53, p<0.001).

Table 3-3. Results of Regression Analyses of Alcohol Outlet Access on Violent Crime Exposure, Baltimore City 2016

	Count of Violent Crimes		Proximity to Nearest Violent Crime[b]		SAI for Seven Nearest Violent Crimes[c]		SAI for Violent Crimes in 0.25-Mile Buffer[d]	
	IRR	95% CI	β	95% CI	β	95% CI	β	95% CI
Raw count of alcohol outlets	1.04***	1.02, 1.05	-0.04*	-0.07, -0.01	0.04**	0.02, 0.07	0.07**	0.02, 0.12
Drug arrests	1.06***	1.05, 1.08	-0.02	-0.05, 0.01	0.02	>-0.01, 0.04	0.09**	0.02, 0.15
Percent African American	1.46***	1.20, 1.77	-0.93***	-1.31, -0.56	0.87***	0.56, 1.18	1.95***	1.08, 2.82
Vacant housing	1.17***	1.09, 1.25	-0.08	-0.23, 0.08	0.14*	0.01, 0.28	0.14	-0.10, 0.38
Median annual household income[a]	0.91***	0.89, 0.93	0.04*	>-0.01, 0.08	-0.05*	-0.07, -0.02	-0.08	-0.17, 0.01
Percent population aged 18-35	1.58	0.98, 2.56	-0.44	-1.17, 0.30	0.50	-0.11, 1.12	0.97	-0.44, 2.39
Population density	0.98***	0.97, 0.98	-0.04***	-0.06, -0.03	0.04***	0.03, 0.05	0.09***	0.06, 0.11
High-density cluster	1.85***	1.59, 2.15	-0.27	-0.54, <0.01	0.29*	0.06, 0.51	1.13***	0.79, 1.47
Count of alcohol outlets divided by total population[a]	1.04***	1.03, 1.06	-0.04**	-0.07, -0.01	0.04**	0.02, 0.07	0.08**	0.03, 0.13
Drug arrests	1.06***	1.05, 1.08	-0.02	-0.05, 0.01	0.02	>-0.01, 0.04	0.08**	0.03, 0.14
Percent African American	1.47***	1.21, 1.78	-0.94***	-1.31, -0.56	0.87***	0.56, 1.18	1.95***	1.08, 2.82
Vacant housing	1.17***	1.09, 1.25	-0.08	-0.23, 0.08	0.14*	0.01, 0.28	0.13	-0.11, 0.38
Median annual household income	0.91***	0.89, 0.93	0.04*	<0.01, 0.07	-0.04*	-0.07, -0.02	-0.08	-0.16, 0.01
Percent population aged 18-35	1.58	0.98, 2.55	-0.43	-1.17, 0.31	0.50	-0.12, 1.11	0.96	-0.45, 2.38
Population density	0.98***	0.97, 0.98	-0.04***	-0.06, -0.03	0.04***	0.03, 0.05	0.09***	0.06, 0.11
High-density cluster	1.84***	1.58, 2.14	-0.27	-0.54, 0.01	0.28*	0.06, 0.51	1.12***	0.78, 1.46
Count of alcohol outlets divided by area[c]	1.03***	1.02, 1.04	-0.03**	-0.06, -0.01	0.03**	0.01, 0.05	0.07***	0.03, 0.10
Drug arrests	1.06***	1.05, 1.08	-0.02	-0.05, 0.01	0.02	>-0.01, 0.04	0.08**	0.02, 0.14
Percent African American	1.44***	1.18, 1.75	-0.92***	-1.30, -0.56	0.86***	0.56, 1.16	1.95***	1.09, 2.82
Vacant housing	1.17***	1.10, 1.25	-0.08	-0.23, 0.08	0.14*	0.01, 0.28	0.13	-0.11, 0.37
Median annual household income	0.91***	0.89, 0.93	0.04*	<0.01, 0.07	-0.04**	-0.07, -0.02	-0.08	-0.16, 0.01
Percent population aged 18-35	1.59	0.98, 2.58	-0.44	-1.17, 0.30	0.51	-0.11, 1.12	0.97	-0.44, 2.38
Population density	0.97***	0.97, 0.98	-0.04***	-0.05, -0.03	0.04***	0.03, 0.05	0.08***	0.06, 0.10
High-density cluster	1.85***	1.9, 2.15	-0.27	-0.54, 0.01	0.28*	0.06, 0.51	1.12***	0.78, 1.46
Count of alcohol outlets divided by total roadway miles[c]	1.04***	1.02, 1.06	-0.04**	-0.08, -0.01	0.05**	0.02, 0.07	0.09***	0.04, 0.14
Drug arrests	1.06***	1.05, 1.08	-0.02	-0.05, 0.01	0.02	>-0.01, 0.04	0.08**	0.02, 0.14
Percent African American	1.43***	1.18, 1.74	-0.92***	-1.29, -0.55	0.86***	0.55, 1.16	1.95***	1.09, 2.81
Vacant housing	1.18***	1.10, 1.26	-0.08	-0.24, 0.08	0.15*	0.02, 0.28	0.14	-0.11, 0.38
Median annual household income	0.91***	0.89, 0.93	0.04*	>-0.01, 0.07	-0.04*	-0.07, -0.02	-0.08	-0.16, 0.01

	Count of Violent Crimes		Proximity to Nearest Violent Crime[b]		SAI for Seven Nearest Violent Crimes[c]		SAI for Violent Crimes in 0.25-Mile Buffer[d]	
	IRR	95% CI	β	95% CI	β	95% CI	β	95% CI
Percent population aged 18-35	1.59	0.98, 2.58	-0.44	-1.17, 0.30	0.50	-0.11, 1.12	0.96	-0.45, 2.37
Population density	0.97***	0.97, 0.98	-0.04***	-0.05, -0.03	0.04***	0.03, 0.05	0.08***	0.06, 0.10
High-density cluster	1.86***	1.60, 2.16	-0.27*	-0.55, >-0.01	0.29*	0.07, 0.51	1.13***	0.80, 1.47
Proximity[e]	0.77***	0.72, 0.83	0.33***	0.19, 0.47	-0.33***	-0.44, -0.22	-0.94***	-1.23, -0.65
Drug arrests	1.06***	1.04, 1.08	-0.01	-0.04, 0.01	0.01	-0.01, 0.04	0.06	>-0.01, 0.11
Percent African American	1.44***	1.18, 1.76	-0.95***	-1.30, -0.61	0.88***	0.61, 1.16	2.15***	1.31, 2.99
Vacant housing	1.13**	1.05, 1.21	-0.03	-0.19, 0.13	0.10	-0.03, 0.23	-0.03	-0.30, 0.24
Median annual household income	0.91***	0.89, 0.93	0.04*	0.01, 0.07	-0.05**	-0.07, -0.02	-0.07	-0.16, 0.01
Percent population aged 18-35	1.31	0.85, 2.02	-0.25	-0.97, 0.47	0.32	-0.27, 0.90	0.38	-0.98, 1.74
Population density	0.97***	0.97, 0.98	-0.04***	-0.05, -0.02	0.03***	0.02, 0.05	0.06***	0.05, 0.08
High-density cluster	1.57***	1.35, 1.83	-0.08	-0.37, 0.21	0.09	-0.13, 0.32	0.56*	0.26, 0.86
SAI – seven[f]	1.69***	1.54, 1.86	-0.50***	-0.70, -0.29	0.46***	0.30, 0.63	1.44***	1.00, 1.87
Drug arrests	1.06***	1.04, 1.07	-0.01	-0.04, 0.01	0.02	>-0.01, 0.04	0.06*	0.01, 0.12
Percent African American	1.24*	1.04, 1.49	-0.76***	-1.10, -0.43	0.70***	0.42, 0.97	1.60***	0.83, 2.38
Vacant housing	1.09*	1.02, 1.16	-0.02	-0.18, 0.14	0.09	-0.04, 0.23	-0.07	-0.34, 0.20
Median annual household income	0.91***	0.89, 0.93	0.04	<0.01, 0.07	-0.04**	-0.07, -0.02	-0.07	-0.15, 0.01
Percent population aged 18-35	1.09	0.72, 1.60	-0.20	-0.92, 0.51	0.29	-0.30, 0.88	0.23	-1.14, 1.60
Population density	0.97***	0.96, 0.97	-0.04***	-0.05, -0.02	0.04***	0.02, 0.05	0.06***	0.05, 0.08
High-density cluster	1.62***	1.40, 1.88	-0.15	-0.43, 0.13	0.17	-0.06, 0.40	0.75***	0.46, 1.05
SAI – 0.5 mile[g]	1.06***	1.04, 1.07	-0.07***	-0.10, -0.03	0.06***	0.04, 0.09	0.22***	0.15, 0.30
Drug arrests	1.06***	1.04, 1.08	-0.01	-0.04, 0.01	0.01	-0.01, 0.04	0.05	-0.01, 0.10
Percent African American	1.42**	1.15, 1.76	-0.95***	-1.31, -0.59	0.87***	0.58, 1.17	2.22***	1.36, 3.08
Vacant housing	1.15***	1.07, 1.23	-0.06	-0.22, 0.10	0.13	>-0.01, 0.26	0.02	-0.23, 0.27
Median annual household income	0.91***	0.89, 0.93	0.03	>-0.01, 0.07	-0.04**	-0.07, -0.01	-0.05	-0.14, 0.04
Percent population aged 18-35	1.34	0.84, 2.14	-0.32	-1.05, 0.41	0.40	-0.21, 1.01	0.49	-0.87, 1.85
Population density	0.97***	0.97, 0.98	-0.04***	-0.05, -0.02	0.04***	0.03, 0.05	0.06***	0.05, 0.08
High-density cluster	1.72***	1.48, 1.99	-0.17	-0.45, 0.11	0.19	-0.03, 0.42	0.77***	0.49, 1.05
Mean – seven[h]	0.60***	0.55, 0.66	0.48***	0.27, 0.69	-0.47***	-0.64, -0.30	-1.53***	-1.96, -1.10
Drug arrests	1.06***	1.04, 1.07	-0.01	-0.04, 0.01	0.01	-0.01, 0.04	0.05	0.01, 0.11
Percent African American	1.70***	1.40, 2.06	-1.08***	-1.45, -0.71	1.00***	0.70, 1.30	2.60***	1.70, 3.50
Vacant housing	1.07*	1.00, 1.15	<0.01	-0.16, 0.16	0.07	-0.06, 0.20	-0.16	-0.43, 0.12
Median annual household income	0.91***	0.89, 0.94	0.04*	<0.01, 0.07	-0.04**	-0.07, 0.02	-0.07	-0.15, -0.01

	Count of Violent Crimes		Proximity to Nearest Violent Crime[b]		SAI for Seven Nearest Violent Crimes[c]		SAI for Violent Crimes in 0.25-Mile Buffer[d]	
	IRR	95% CI	β	95% CI	β	95% CI	β	95% CI
Percent population aged 18-35	1.22	0.80, 1.86	-0.28	-0.99, 0.44	0.35	-0.24, 0.94	0.37	-0.96, 1.71
Population density	0.97***	0.96, 0.97	-0.03***	-0.05, -0.02	0.03***	0.02, 0.04	0.06***	0.04, 0.07
High-density cluster	1.43***	1.23, 1.67	-0.01	-0.32, 0.30	0.03	-0.21, 0.28	0.28	-0.02, 0.58

*p<0.05, **p<0.01, ***p<0.001
SAI=Spatial accessibility index; CI=Confidence Interval
[a]Median annual household incomes greater than $250,000 are censored.
[b]Calculated as the minimum distance from the census block group centroid to the closest violent crime.
[c]Calculated by summing the inverse distances from the census block group centroid to each of the seven closest violent crimes.
[d]Calculated by summing the inverse distance from the census block group centroid to each violent crime located within a 0.25-mile buffer.
[e]Calculated as the minimum distance from the census block group centroid to the closest alcohol outlet.
[f]Calculated by summing the inverse distances from the census block group centroid to each of the seven closest alcohol outlets.
[g]Calculated by summing the inverse distance from the census block group centroid to each alcohol outlet located within a 0.25-mile buffer.
[h]Calculated as the average distance from the census block group centroid to the seven closest alcohol outlets.

Table 3-4 also shows the R^2 and AIC values for each model fit. The models that used a count of violent crime (models 1-8, R^2=8.06-9.60) and proximity to the nearest violent crime (models 9-16, R^2=21.63-23.96) explained the least variability. Models that used the SAI for the seven nearest violent crimes (models 17-24, R^2=30.24-32.92) and the SAI for violent crimes within a 0.25-mile buffer (models 25-32, R^2=37.6-45.67) explained the most variability. Within each method of calculating the violent crime outcome, the proximity and spatial access methods for calculating alcohol outlet access consistently yielded the highest R^2 values. Model 8 (mean distance to the seven nearest outlets) had the highest R^2 among the models that used a count of violent crime (R^2=9.60), model 14 (SAI for seven nearest outlets) provided the highest R^2 among the models that used proximity to the nearest violent crime (R^2=23.96), model 22 (SAI for the seven nearest outlets) had the highest R^2 among the models that used a SAI for the seven nearest violent crimes 3 (R^2=32.92), and model 32 (mean distance to the seven nearest outlets) had the largest R^2 among the models that used a SAI for violent crimes within a 0.25-mile buffer (R^2=45.67).

Table 3-4. Akaike's Information Criterion for Regression Analyses of Alcohol Outlet Access on Violent Crime Exposure, Baltimore City 2016

Alcohol Outlet Access	Count of Violent Crimes		Proximity to Nearest Violent Crime[a]		SAI for Seven Nearest Violent Crimes[b]		SAI for Violent Crimes in 0.25-Mile Buffer [c]	
	R^2	AIC	R^2	AIC	R^2	AIC	R^2	AIC
Raw count of alcohol outlets	8.06	5,879.45	21.63	1,982.38	30.24	1,755.80	37.45	2,528.35
Count of alcohol outlets divided by total population	8.23	5,868.58	21.85	1,980.70	30.48	1,753.78	37.65	2,526.36
Count of alcohol outlets divided by total area in square miles	8.11	5,876.46	21.83	1,980.88	30.47	1,753.78	37.86	2,524.37
Count of alcohol outlets divided by total roadway miles	8.09	5,877.46	21.78	1,981.27	30.44	1,754.08	37.86	2,524.37
Proximity to nearest outlet[d]	8.57	5,846.72	23.39	1,968.73	32.39	1,737.05	43.41	2,468.30
SAI for seven nearest outlets[e]	9.28	5,801.64	23.96	1964.26	32.92	1,732.35	45.30	2,447.96
SAI for outlets inside 0.5-mile buffer[f]	8.54	5,849.09	23.04	1,971.53	31.68	1,743.33	44.77	2,453.77
Mean distance to seven nearest outlets[g]	9.60	5,781.43	23.57	1,967.35	32.48	1,736.24	45.67	2,443.93

AIC=Akaike's Information Criterion; SAI=Spatial access index
[a]Calculated as the minimum distance from the census block group centroid to the closest violent crime.
[b]Calculated by summing the inverse distances from the census block group centroid to each of the seven closest violent crimes.
[c]Calculated by summing the inverse distance from the census block group centroid to each violent crime located within a 0.25-mile buffer.
[d]Calculated as the minimum distance from the census block group centroid to the closest alcohol outlet.
[e]Calculated by summing the inverse distances from the census block group centroid to each of the seven closest alcohol outlets.
[f]Calculated by summing the inverse distance from the census block group centroid to each alcohol outlet located within a 0.25-mile buffer.
[g]Calculated as the average distance from the census block group centroid to the seven closest alcohol outlets.

The largest gains in AIC came from choices in calculating the crime variable. The AIC was nearly cut in half moving from model 1-8 with a count of violent crime (AIC=5,781-5,879) to model 25-32 with the SAI for violent crimes within a 0.25-mile radius (AIC=2,444-2,528). Models 9-16 that used proximity to the nearest violent crime (AIC=1,964-1,982) and models 17-24 that used the SAI for the seven nearest violent crimes (AIC=1,732-1,755) had AICs that were even lower. Similar to the trends in R^2, the proximity and the spatial access methods of calculating alcohol outlet access consistently yielded lower AICs than models that used counts of alcohol outlets. The mean distance to the seven nearest alcohol outlets had the lowest AIC among the models that used counts of violent crime (model 8, AIC=5,781) as well as models that used a SAI with a 0.25-mile buffer (model 32, AIC=2,444). The SAI for the seven nearest alcohol outlets yielded the lowest AIC among the models that used proximity to the nearest violent crime (model 14, AIC=1,964) and the SAI for the seven nearest crimes (model 22, AIC=1,732).

Conclusion

Measuring the number and location of alcohol outlets are critical for understanding and predicting the potential negative impact of those outlets on surrounding communities. Effective, evidence-based policy must begin with accurate measurement of the alcohol environment. In this analysis, the proximity and spatial access methods performed far better analytically than the count methods. Combining the proximity to the nearest alcohol outlet and a SAI of the seven closest crimes had the lowest AIC. Thus, this model provides a reasonable fit, especially if available resources in terms of data and analytic capability prohibit calculating spatial access methods of both the independent and dependent variables. Ultimately, this analysis concludes that spatial access methods offer the most precise method of quantifying the alcohol environment, which is consistent with CDC guidance and Grubesic, Wei, Miller, & Pridemore's (2016) previous analysis [156, 158]. The rationale for this conclusion is outlined below.

In particular, SAIs yielded the most precise summary of Baltimore's alcohol environment and violent crime trends. The count methods mischaracterized large CBGs in industrial areas, because they were unable to detect the distribution of the outlets. The mischaracterized CBGs tended to have several outlets located along the CBG boundary. Counts treated these outlets as if they were distributed evenly across the CBG, which led the method to conclude there was high availability across the CBG when the majority of the CBG had relatively low access. In contrast, the proximity and average distance methods that did not use containers showed evidence of spatial smoothing. These methods used a broad brush to characterize the alcohol outlet access; therefore, they were less likely to detect nuanced changes across neighboring CBGs. While there was some evidence of spatial smoothing in the SAIs using a seven-outlet choice set and a 0.5-mile buffer, it was less pronounced than was the case with other methods. While the SAI for the seven nearest outlets and the mean distance to the seven nearest outlets use the same numbers to measure alcohol outlet spatial access, they weight the numbers differently. The SAI for the seven nearest crimes weights closer outlets more heavily, while the mean distance to the seven nearest outlets weights outlets furthest away most heavily. In the context of harms related to access to alcohol outlets, assigning greater weights to closer outlets is more logical because the harms increase as distance to outlets decrease.

The SAIs provided the most accurate summary of the alcohol environment, but they had different strengths and weaknesses. The SAI that used the seven nearest alcohol outlets outperformed the SAI with a buffer in areas with low access to alcohol outlets. In particular, this choice set method drew data from adjacent areas to capture access in these areas. On the other hand, the SAI with the buffer suffered from edge effects, and consequently assigned low access areas a value of zero if there were no outlets within 0.5 miles. This created a variable with a bimodal distribution with one peak for CBGs with no alcohol outlets within 0.5 miles and another peak for CBGs that had at least one alcohol outlet within this range. The SAI with the choice set approach yielded a continuous variable that was roughly log-normal.

However, the SAI with a buffer provided a more accurate summary of high alcohol outlet density areas. The alcohol outlet SAI with the choice set characterized a few of the high-density areas along the Inner Harbor as having lower access than the SAI with the buffer, and the violence SAI with the choice set categorized downtown as having lower crime access than the violence SAI with the buffer. This difference likely arises because the buffer approach accounts for both the number and the distribution of the alcohol outlets in the area. For example, consider two cities each with a downtown zone that is 0.5 miles long. City A has seven outlets downtown while City B has those seven outlets plus another 20 outlets in the downtown area. These two configurations would look identical using the choice set approach with seven outlets even though residents in City B have greater access to alcohol outlets. Thus, researchers need to consider the ideal choice set size to capture alcohol outlet access in low- and high-density areas.

Regression results highlighted the advantages of the proximity and spatial access methods over count methods. Within each method of calculating the violent crime variable, the models with the lowest AIC either used a proximity or spatial access method or a combination of the two. The lowest AIC was for the model that used proximity to alcohol outlets and the violence SAI using the seven nearest crimes. To interpret the AICs for the various models, one must account for variable range as well as model efficiency. The models that used a count of violent crime had the lowest model efficiency despite a modest range (1,215). The relatively low AICs for the models with a proximity method of violent crime likely benefitted from the extremely narrow range of the dependent variable (0.77 miles). However, the models with the SAI for violent crimes explained substantially more variability with high model efficiency.

The high-density cluster variable was most often significant in models that used a count to measure alcohol outlet access. This suggests that information about density improved these models, but this information was less necessary for spatial access methods that already accounted for clustering.

There is often debate over how to best refine count methods through a reasoned choice of a denominator [55, 83, 87, 115, 159, 169-171]. This analysis compared the most common denominators for counts of alcohol outlet access. For the majority of models, the population-based denominator tended to have the highest R^2 across models and the roadway miles-based denominator tended to have the lowest. This trend was reversed in the AICs, again suggesting that the population-based denominator performed the best in this setting. However, counts do not capture accessibility (i.e., how hard or easy it is to get to the outlets) and cannot detect clustering of alcohol outlets. The results from these analyses suggest that this debate misses the larger issue of how researchers can integrate measures of accessibility (to measure both the number of outlets and how easy/hard it is to reach those outlets) into their research if they have street-level data.

To date, the authors are unaware of any guidance for the optimal number of outlets to use to define a choice set for SAIs. To address this gap, a sensitivity analysis was performed to determine the statistical consequences of varying the choice set size. The analysis tested choice set sizes ranging from 3 to 50. Across the regressions, the regression coefficient increased by approximately 0.1-0.2 per every five observations added to the spatial access calculation. In addition, the AIC decreased by about one unit until the set included 25 outlets, where the AIC stabilized. Lastly, the SAIs with larger choice set sizes characterized high-density areas more accurately than the original measure with seven alcohol outlets. While this provides statistical evidence of some benefit for larger numbers of observations in SAIs, this benefit may evaporate in the face of real-world conditions. Among the Baltimore CBGs that contain at least one alcohol outlet, the average CBG has five to six outlets. This means a choice set of seven includes the outlets inside the CBG and a few outlets just over the CBG boundary. In contrast, a choice set of 25 outlets provides a smoothed estimate of four to five CBGs. This will yield a statistically stable estimate but measures an average meso-level effect instead of a local, micro-level effect. This sensitivity analysis recommends using a choice set size of two times the average number of alcohol outlets in a CBG among CBGs that contain outlets for a micro-level effect. In Baltimore, that is a choice set size of 10 outlets.

The choice set size likely differs for alcohol outlets and violent crime. From 2012 to 2016, the average CBG contained 77 violent crimes. This means that SAI with a choice set of seven violent crimes used less than 10% of the data for that CBG. A second sensitivity analysis was conducted to determine the statistical consequences of different choice set sizes for violent crime. The sensitivity analysis included choice set sizes ranging from 7 to 200 crimes. Each additional 10 crimes added to the crime SAI reduced the AIC by 30 to 75 points, with larger reductions in the AIC for the initial additions to the choice set size. This analysis recommends setting choice set sizes between the 25th and 50th percentile for violent crime. Ideally, measures of violent crime will provide local effects within each CBG to avoid double counting crimes across CBGs.

This analysis has several limitations. First, the analysis only assessed total alcohol outlet access and did not disaggregate by outlet type for the sake of simplicity. While this facilitated comparisons, it is possible that the statistical advantages of the respective methods could depend on the types of outlet and different methods more accurately capture dynamics of subtypes of outlets. The analysis was also unable to determine whether all alcohol outlets were still open at the time of the analysis, as it is possible that some outlets closed in the 16 months between data generation and analysis. Also, the BCPD data only include crimes that were reported to the police. It is possible that there is underreporting, though this underreporting is not anticipated to vary across CBGs.

Finally, it is possible that the relative advantages and disadvantages of these methods depend on the context. Findings described here are specific to Baltimore City, which has unique demographics and history. Baltimore's population has steadily fallen since its peak of 950,000 residents in the 1950s. During this population decline, the number of alcohol outlets remained fairly constant, leading Baltimore residents to have high exposure to alcohol outlets. Departure of numerous residents also led to large swaths of vacant homes, which contributed to social disorganization that has been exacerbated by active drug markets and high poverty rates in these neighborhoods. Baltimore is also a city comprised of a patchwork of neighborhoods, which can cause demographics to shift substantially across small geographic areas (e.g. within a CBG). Consequently, Baltimore has sizable health disparities which may or may not map accurately to individuals CBGs; life expectancy differs by as much as 20 years across neighborhoods [210]. Detecting an association between alcohol outlet access and violence in a city with high crime, poverty, and a range of social issues suggests that the association between alcohol outlets and violence is robust. While Grubesic al. reached similar conclusions to those arrived at here using data from Seattle, Washington, [158], future research should determine whether spatial access methods are superior in cities with different demographics.

Still, this research provides analytical evidence to help inform future investigations into alcohol outlet access. Future research should consider adding non-spatial dimensions of access to more completely measure access. This would permit researchers to determine which of the five types of access play the largest role in determining individual behavior. The three other dimensions of access proposed by Penchansky & Thomas are affordability, acceptability, and accommodation [152]. In addition, no alcohol outlet access studies to date have captured the construct of diversity of outlet access. Diversity would capture the access to different types of alcohol outlets (e.g., on- and off-premise) [211]. While this research could all inform policy-relevant discussions, it would require combining administrative data with observational and/or survey data. Along these same lines, it may be helpful to point out that the word "access" defines both a noun ("potential" access, or the qualities of the built environment) and a verb ("realized" access, or patronizing the outlets) [153]. Understanding this distinction holds potential promise for future research. To date, the authors are unaware of any studies that have measured "realized" access to characterize the types of situations in which the physical environment leads to behavior change.

This paper confirms Grubesic et al.'s findings about the importance of using spatial access methods in assessing alcohol outlet access. The advantages over count- or distance-based methods appear substantial for both independent and dependent variables, at least in urban settings. Clarification of these methodological issues also helps to explains some of the inconsistencies in prior analyses of the relationship between alcohol outlet density and various negative outcomes. Future analyses in urban settings should employ spatial access methods to improve the precision and stability of estimates of the impact of alcohol outlets on their surrounding communities.

Chapter 4: Outlet Type, Access to Alcohol, and Violent Crime

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Abstract

Introduction: While there is overwhelming data supporting the association between alcohol outlet density and violent crime, there remain conflicting findings about whether on- or off-premise outlets have a stronger association with crime. This inconsistency may be in part a result of the methods used to calculate alcohol outlet density and violent crime. The present analysis uses routine activity theory and spatial access methods to study the association between access to alcohol outlets and violent crime include type of outlet and type of crime in Baltimore, Maryland.

Materials and Methods: The data in this analysis include, alcohol outlets from 2016 (n=1,204), violent crimes from 2012-2016 (n=51,006) and markers of social disorganization, including owner-occupied housing, median annual household income, drug arrests, and population density. The analysis used linear regression to determine the association between access to alcohol outlets and violent crime exposure.

Results: Each 10% increase in access to alcohol outlets was associated with a 4.2% increase in exposure to violent crime (β=0.43, *95% CI* 0.31, 0.59, p<0.001). A 10% increase in access to off-premise (4.4%, β=0.45, *95% CI* 0.31, 0.59, p<0.001) and LBD-7 outlets, which are combined off- and on-premise licensed outlets, (4.2%, β=0.43, *95% CI*0.32, 0.54, p<0.001)had a greater association with violent crime than access to on-premise outlets (3.0%, β=0.31, *95% CI* 0.20, 0.41, p<0.001).

Conclusions: Access to outlets that allow for off-site consumption had a greater association with violent crime than outlets that only permit on-site consumption. Future research should explore whether the lack of effective place managers and capable guardians in and around off-premise outlets attract or multiply violent crime.

Introduction

Alcohol-attributable violence is a significant public health problem. It is more common than drink driving crashes in the United States (US) [212]. Every day, there are 43 homicides in the US, and excessive drinking (e.g., binge drinking, heavy drinking) is responsible for 20 of them [4]. Alcohol plays a role in both violence perpetration and victimization [3, 213], likely through alcohol's disinhibiting effects that can make people more likely to perpetrate an attack as well as less physically or mentally likely to resist an attack. Two out of five homicide victims test positive for alcohol [214], and women who average six or more drinks per day are more likely to become a sexual assault victim [215]. All of these associations mean that alcohol-attributable violence carries a large price tag; crimes that result from excessive drinking costs the US $36.7 billion in 2010 [216].

Research literature on the relationship between alcohol outlets and violent crimes demonstrates that violent crimes are associated with greater access to alcohol outlets [11-13]. The literature, however, is not as conclusive on whether on-premise (e.g., bars) [65, 79, 82, 121] or off-premise alcohol outlets (e.g., liquor stores) [61, 81, 82, 90, 99, 122, 198] have a stronger association with violent outcomes. Hypotheses around differences in the association between on- and off-premise alcohol outlets and violent crime are related in part to routine activity theory.

Routine activity theory is an ecologic model that describes how places bring people together in ways that create or suppress opportunities for violent crime. The theory is based on the idea that crime occurs in times and locales where motivated offenders are in close proximity to susceptible targets and supervision is low [133]. From this perspective, alcohol outlets are hypothesized to be associated with violent crime because they are often attract individuals who are coming to purchase alcohol and they are often located in areas with reduced guardianship, like retail districts [79]. In addition, other neighborhood types that rarely have responsible supervisors, like socially disorganized neighborhoods, may also be associated with both alcohol outlet access and violent crime [92, 188, 217]. In particular, markers of socially disorganized areas like liquor stores and abandoned buildings facilitate crime by providing settings for motivated offenders to meet and help each other escape after the crime [133]. Further, alcohol consumption can often serve as a "precriminal situation," increasing both offender motivation and target susceptibility [60, 79, 217].

Alcohol outlets themselves may have criminogenic properties, and these properties may differ by outlet type. One way that outlet types could shape criminogenic properties is through the types of place managers they employ. Place managers prevent crime by controlling the physical environment [217]. They tend to be most effective when they are in close proximity to and have unobstructed view of potential offenders and have a sense of duty to maintain order in the establishment [217]. In on-premise establishments, waitresses, bartenders, bouncers, and disc jockeys can all serve as place managers, and these people tend to be in close proximity to patrons for the duration of the time that the patron drinks in the establishment [81, 122, 135]. In such circumstances, outlet staff may use de-escalation techniques or ask patrons to leave if violence begins to spark. However, some on-premise outlets will serve as crime generators if they have staff or circumstances that make it easier for offenders to commit a crime, such as bartenders who serve alcohol to minors or serve past intoxication, bring together people who otherwise would not interact, have poor lighting, and/or are located in high-density areas that produce streams of suitable targets at closing time [217].

On the other hand, place managers (e.g., sales clerks) in off-premise outlets have a more limited role. They often only observe patrons briefly at the point of sale. Alcohol is also less expensive at off-premise outlets, and patrons can buy greater quantities [155, 181, 218]. The physical design of off-premise outlets can also limit place managers' effectiveness, because these outlets often have plexiglass barriers separating place managers from patrons [90]. In addition, off-premise outlets may be adjacent to alleys or parking lots that can also act as "de facto bars/taverns" without any place managers at all [96].

In line with these hypotheses, most studies that compare on- and off-premise outlets have found a stronger association between off-premise alcohol outlets and violent crime overall (i.e., homicide, aggravated assault, sexual assault, and robbery) [61, 188], and separately, assault [79, 94, 95] and robbery [138]. Using data from Baltimore City, Jennings et al. (2014) found that each additional off-premise alcohol outlet in a census tract was associated with a larger increase in violent crime than on-premise outlets [219]. Pridemore & Grubesic (2012) in Cincinnati found stronger associations between violent crime and off-premise outlets compared to bar and restaurant availability [92]. In Philadelphia, the same authors found that off-premise outlets had an association six times stronger than the association with on-premise outlets on assaults [95].

The differences in location of consumption at on- and off-premise outlets present an inherent measurement problem in quantifying harms more broadly, and specifically the association with violent crime. Harms tend to occur near the location of consumption. Patrons drink on-site in on-premise outlets. However, patrons of off-premise outlets may purchase alcohol, consume it at home or at some other location distant from the point of purchase, and then commit a violent act. Others may consume the alcohol close to the point of purchase and end up committing a violent act near the outlet [96]. This is known as "diffusion bias," and it suggests that researchers may need to use the most sensitive methods possible to detect the nuanced spatial relationships between alcohol outlets and related harms [86, 182].

Even if the associations tend to be larger for off-premise outlets overall, routine activity theory hypothesizes that some on-premise outlets contribute to violent crime, and the literature supports this. A study by Roncek & Maier (1991) investigated the role of one type of on-premise outlets - bars/taverns - by city block in Cincinnati and found that each additional bar/tavern on a block was associated with a 17.4% increase in violent crime [132]. Further, a study of the Buckhead area in Atlanta, Georgia found that decreases in on-premise alcohol outlet density were associated with proportional decreases in violent crime [184].

It is possible that the studies finding a greater association between on-premise outlets and violent crime [65, 68, 78, 79, 86, 121] suffer from methodological weaknesses. For example, three studies that concluded a stronger association between violent crime and on-premise outlets used the victim's residential address instead of the location of the assault [68, 78, 79]. Another study that failed to detect an association between off-premise outlet availability and violent crime may have been underpowered to detect off-premise associations because the study area had few off-premise outlets [121]. Lastly, the findings from a study from the North Island of New Zealand demonstrated larger associations for bar and clubs than off-premise outlets might be attributable to the large unit of analysis – census area units, which have a maximum of 5,000 residents and approximately correspond to suburbs in urban areas [86].

In addition, all of these previous studies used count-based methods of measuring alcohol outlet availability, whether they were raw counts [78] or weighted by population [86], area [68], or roadway miles [65, 79, 121]. Recent guidance [156] and analyses [158] highlight the limitations of count-based methods to measure spatial access of alcohol outlets. In particular, counts are less sensitive [158] and treat alcohol outlets as if they were evenly distributed within the geographic unit of analysis [156]. This assumption is problematic when investigating the role of alcohol outlets in violent crime, because alcohol outlets often concentrate in clusters and clustering is associated with violence [96, 184, 220]. Distance-based and spatial access methods are alternatives to count-based methods, and recent literature and guidance recommends spatial access methods to overcome these limitations [156, 158]. Spatial access methods combine information about the number and locations of alcohol outlets to simultaneously measure availability and accessibility of alcohol outlets [153]. While spatial access methods encompass a broad set of tools, one common approach is to calculate a spatial accessibility index (SAI) by summing the inverse distances from a reference point to a set of alcohol outlets. This SAI can then be interpreted as a score that quantifies the access to alcohol outlets and discounts outlets that are farther away.

The objectives of this study were to determine 1) the overall association between alcohol outlet spatial access and violent crime in Baltimore City, Maryland from 2012-2016; 2) whether three specific types of alcohol outlets - on-premise, off-premise, and LBD-7 (i.e. LBD-7 are defined as outlets permitted to sell both on and off premise) are associated with violent crime; and 3) whether specific outlet types are associated with specific types of crime including homicide, aggravated assault, sexual assault, and robbery. Based on routine activity theory, we hypothesize that greater exposure to off-premise outlets will have a stronger association with violent crime exposure than on-premise outlet exposure. This study uses spatial access methods to overcome common limitations of previous research. Of note, interpretations for spatial access methods are different from those for traditional count-based methods that model alcohol outlet availability and number of violent crimes or violent crime rates. In particular, our alcohol outlet variables measure alcohol outlet *access*, and our violent crime variables measure violent crime *exposure* in a CBG. In the final models, we controlled for neighborhood factors including percent African American, owner-occupied housing, median annual household income, population density, and drug arrests.

Materials and Methods

Geographic Unit of Analysis

This analysis uses 2010 census block groups (CBGs) as the unit of analysis, which is the smallest geographical unit for which the United States Census Bureau publishes unrestricted data. Baltimore has 653 CBGs. Fifty-four (8.3%) CBGs did not have available income data due to the following three (0.5%) had no residents and the other 51 (7.8%) were suppressed. The final study sample included 599 CBGs. The 599 CBGs ranged from 0.02 to 1.01 square miles (mean: 0.11 mi^2) and contained between 141 and 3,828 residents (mean: 983 residents).

Measures

Alcohol Outlets

Data were obtained from the Baltimore City Board of Liquor License Commissioners for 1,218 licensed alcohol establishments as of July 4, 2016. Fourteen (1%) establishments were excluded due to limited days or hours of sale, including Pimlico Race Track (n=1), Baltimore Zoo (n=1), arenas (n=7), and municipal licenses (n=5). This resulted in a final list of 1,204 establishments (518 [43%] on-premise outlets, 264 [22%] off-premise outlets, and 421 [35%] LBD-7 outlets). The addresses for these 1,204 outlets were geocoded using an address locator in ArcGIS and StreetMap 2013.

Four spatial accessibility indices (SAIs) were calculated to measure the spatial access of alcohol outlets using an inverse distance total, including: 1) Total alcohol outlet spatial access, 2) On-premise outlet spatial access, 3) Off-premise outlet spatial access, and 4) LBD-7 outlet spatial access. Previous work by the study authors found that a SAI choice set size of 10 outlets explained more variation than previous set sizes of seven outlets [184] and were able to detect clustering [221]. Thus, we calculated each SAI by summing the inverse distance from each CBG centroid to the 10 nearest outlets [156]. We did not restrict distance to the CBG borders to find the 10 closest outlets, and a set size of 10 outlets will smooth over three CBGs on average [221]. The final SAIs measure the exposure of CBGs to alcohol outlets and weight alcohol outlets that are located closer to the CBG centroid more heavily than those that are further away. The alcohol outlet SAIs were transformed using the natural logarithm in order to adjust for positive skew.

Violent Crime

We obtained victim-based violent crime from the Baltimore Police Department. The violent crime data were from January 1, 2012 through December 31, 2016, and the drug arrest data were from January 1, 2016 through December 31, 2016. Violent crime was defined using the Federal Bureau of Investigation (FBI's) Uniform Crime Reporting (UCR) definition: homicide, forcible sexual assault, aggravated assault, and robbery [205]. All of these crimes involve force or threat of force [205].

We also constructed SAIs to measure violent crime exposure. The ideal choice set sizes for violent crime were different than for alcohol outlets because there are more violent crimes than alcohol outlets in Baltimore CBGs. Previous research by study authors concluded that the choice set size for violent crimes should equal roughly the median number of crimes in the CBGs [221]. The median CBG contained 62 violent crimes, 30 aggravated assaults, 1 sexual assault, 1 homicide, and 25 robberies. We increased the choice set sizes for sexual assault and homicide to 10 so the SAIs would be able to detect clustering. Thus, the final choice set sizes were 62 total violent crimes, 10 homicides, 30 aggravated assaults, 10 sexual assaults, and 25 robberies. Like the alcohol outlet SAIs, we calculated the violent crime SAIs by summing the network inverse distance from each CBG centroid to the N closest violent crime types, where N is the choice set size for the particular type of crime. All violent crime exposure SAIs were transformed using the natural logarithm to adjust for positive skew and mitigate the effect of outliers.

Covariates

We selected covariates using routine activity theory and previous empirical research. We had two sets of these contextualizing variables, including those for the bivariate analyses that examine the types of Baltimore neighborhoods that have higher access to alcohol outlets and regression coefficients that determine the association between alcohol outlet access and violent crime exposure. These variables included percent African American, median annual household income, percent female-headed households, percent of families living in poverty, percent owner-occupied housing, percent of adults with a college degree, percent owner-occupied housing, population density and drug arrest counts. Lower levels of owner-occupied housing are anticipated to increase the risk of violent crime because renters tend to be less invested in the social control of the neighborhood [133]. From a routine activity perspective, this means areas with more renters will have fewer invested place managers. In addition, areas with high population density and low median household incomes tend to have higher levels of violent crime [79, 222] and suffer greater effects of high concentrations of alcohol outlets [68]. Lastly, we used percent African American, because African Americans tend to drink less than people of other races [2]. Four variables were combined into a social disadvantage index as follows:

([(% female-headed households/10) + (% families living in poverty/10)] – [(% owner-occupied housing/10) + (% adults with college degree/10)]) / 4

The social disadvantage index is designed so each unit increase corresponds to a 10% increase in the two disadvantage items (i.e., female-headed households and families living in poverty) and a 10% decrease in the two advantage items (i.e., owner-occupied housing and adults with college degree) [219]. Socio-demographic variables at the CBG level were obtained from the American Community Survey (ACS) 2016 five-year estimates and drug arrest counts were obtained from the BPD.

We used percent African American, income, and the social disadvantage index in the bivariate analyses, because these were anticipated to describe the community context for areas with higher or lower alcohol outlet access. Regression covariates included percent African American, percent owner-occupied housing, median annual household income, population density, and number of drug arrests. ACS censored median annual household income at $250,000 per year, and we scaled it so a one-unit increase represented an addition $10,000. We also scaled and log transformed the drug arrest variable so each unit increase represents the natural log of 10 drug arrests. The means, standard deviations, and minimum and maximum values are shown in Table 4-1.

Analyses

As a part of exploratory analyses, we created choropleth maps to examine the distribution of alcohol outlet and violent crime exposure. Student t-tests with unequal variances were used to compare spatial access by outlet type and demographic characteristics to describe the types of neighborhoods that have higher or lower access to alcohol outlets. In particular, e compared areas of high African American populations (≥50% African American), low-income areas (<$25,000 median annual household income), high-income areas (≥$75,000 median annual household income), disadvantaged areas (social disadvantage <-3.77 [lowest quartile]), and advantaged areas (social disadvantage > 0 [upper quartile]).

Multiple linear regressions were used to determine the association between spatial access of alcohol outlets and violent crime exposure at the CBG level. Model 1 includes the total alcohol outlet SAI and the total violent crime SAI. Models 2 through 5 examined the association between total violent crime exposure and each outlet type, and models 6 through 9 tested the associations between all outlet types and homicide, aggravated assault, sexual assault, and robbery separately. All non-significant regression covariates were removed to yield the most parsimonious model. We assessed collinearity using correlations between regression coefficients and variance inflation factors. The three alcohol outlet SAIs were correlated, but all VIFs were less than three, indicating that they provided stable estimates.

The analysis used Moran's Index (Moran's I) to measure spatial dependence among the violent crime exposure indices and as a diagnostic check for residual spatial variation. We added spatial lag terms for the alcohol outlet SAIs to see if they accounted for additional residual spatial variation and if the alcohol outlet spatial access in adjacent CBGs was associated with the violent crime exposure index. These terms did not account for any additional spatial dependence and they were excluded from the final models. The residual spatial variation was small (Moran's I 0.04-0.15) and the regression coefficients for the alcohol outlet SAIs were highly significant. Thus, the results of this analysis are approximately correct. We used traditional diagnostic procedures during the regression fitting process, including leverage, Cook's distance, and studentized residuals. In the end, we concluded that no CBGs had an undue influence on the regression results, and all 599 CBGs remained in the analysis.

Results

Table 4-1 presents descriptive analyses for Baltimore City in 2016 by CBGs, and Figure 4-1 presents choropleth maps showing the distribution of alcohol outlet and violent crime exposure. Overall, a substantial number of CBGs, particularly those in north Baltimore and near city borders, had low spatial access of alcohol outlets and violent crime. Violent crime exposure tends to concentrate in downtown Baltimore (near the city center); the highest violent crime exposures are in a band that extends 1.5 miles north and 2.5 miles to the east and west of downtown. When looking at specific types of violent crime, exposure to aggravated assaults (mean SAI=5,443.5) was notably higher than robberies (mean SAI=1,615.7), homicide (mean SAI=1,044.5), and sexual assault (mean SAI=44.84). Homicides concentrate along the edge of industrial areas in West Baltimore, particularly in CBGs approximately two miles west and northwest of downtown Baltimore. Aggravated assault, sexual assault, and robbery exposure tend to concentrate in the city center, with aggravated assaults and sexual assaults having slightly higher exposure in South Baltimore and robbery having greater exposure along the Inner Harbor (an entertainment zone).

Figure 4-1. Distribution of Exposure to Alcohol Outlets and Violent Crime in Baltimore

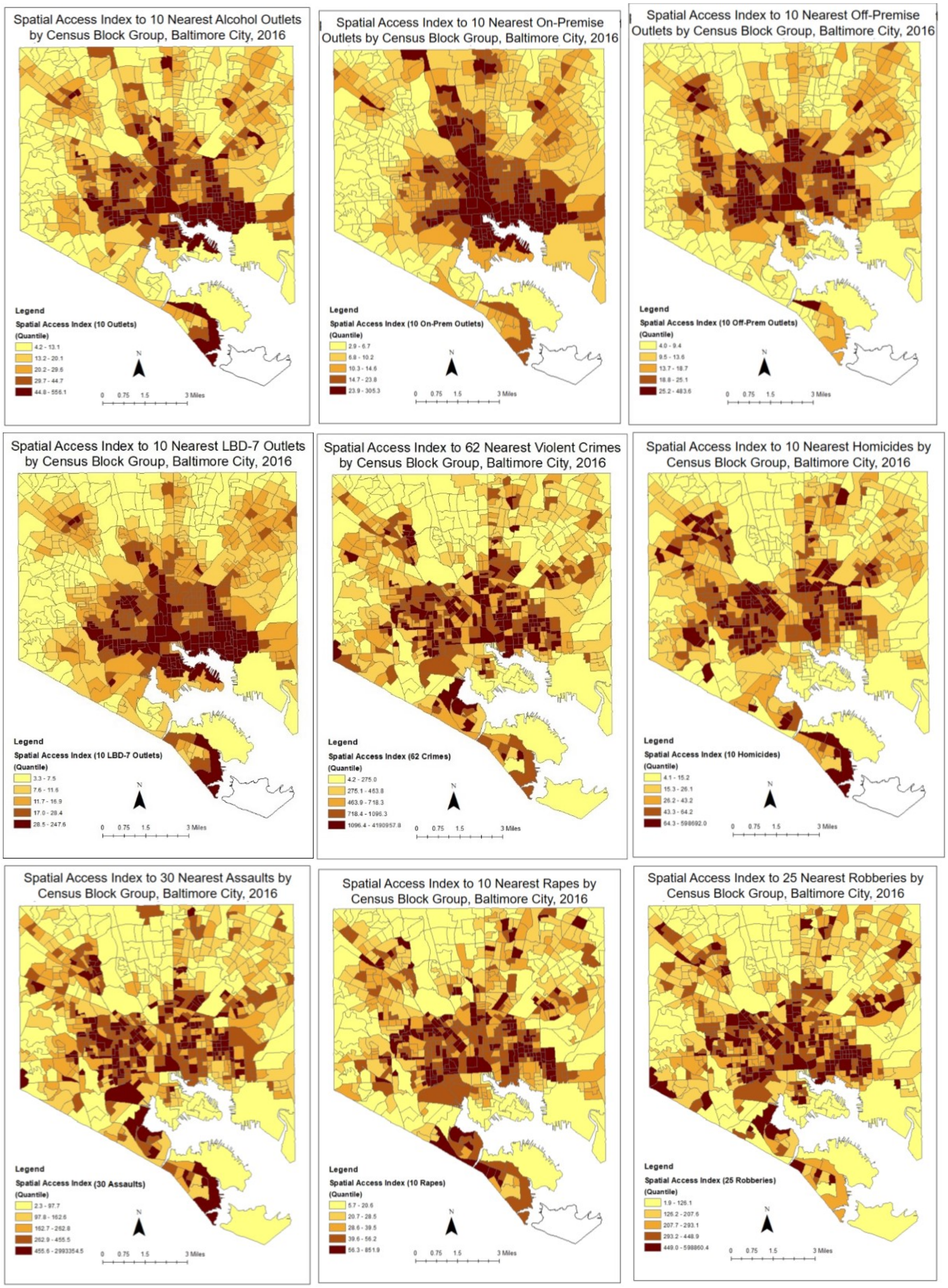

Table 4-1. Descriptive Statistics by Census Block Group, Baltimore City (n=599)

Variable	Mean	SD	Min	Max
Violent Crime SAI				
Total Crime[a]	8,152.63	171,413.20	53.99	4,190,958.00
Homicide[b]	1,044.54	24,460.19	4.11	598,692.00
Aggravated Assault[c]	5,443.50	122,308.40	15.11	2,99,335.00
Sexual assault[d]	44.84	56.97	5.73	851.88
Robbery[e]	1,615.66	25,285.34	26.89	98,860.40
Alcohol Outlet SAI				
All Outlets[f]	33.34	36.85	4.20	556.11
On-Premise Outlets[g]	18.44	22.03	2.94	305.26
Off-Premise Outlets[h]	18.88	21.49	3.95	483.56
LBD-7 Outlets[i]	20.39	19.67	3.32	148.09
Drug Arrests	11.6	18.3	0.0	183.0
Percent African American	66.0%	35.3%	0.0%	100.0%
Median annual household income[j]	$47,786.48	$29,056.48	$8,281.00	$250,000.00
Population density[j]	13,935	9,041	306.52	57,500
Percent owner-occupied housing	0.49	0.25	0.00	100.00
Social disadvantage index[k]	-1.76	3.01	-10.77	8.79

SD = Standard deviation of the mean; Min = Minimum value; Max = Maximum value; SAI = Spatial accessibility index
[a]Calculated as the sum of the inverse distance to the 62 nearest violent crimes.
[b]Calculated as the sum of the inverse distance to the 10 nearest homicides.
[c]Calculated as the sum of the inverse distance to the 30 nearest aggravated assaults.
[d]Calculated as the sum of the inverse distance to the 10 nearest sexual assaults.
[e]Calculated as the sum of the inverse distance to the 25 nearest robberies.
[f]Calculated as the sum of the inverse distance to the 10 alcohol outlets nearest to the CBG centroid.
[g]Calculated as the sum of the inverse distance to the 10 on-premise outlets nearest to the CBG centroid.
[h]Calculated as the sum of the inverse distance to the 10 off-premise outlets nearest to the CBG centroid.
[i]Calculated as the sum of the inverse distance to the 10 LBD-7 outlets nearest to the CBG centroid. LBD-7 outlets are bars/taverns that are permitted to sell alcohol for on- and off-premise consumption.
[i]Median annual household income is censored at $250,000.
[j]Measured as people per square mile.
[k]Calculated as ([(% female-headed households/10) + (% families living in poverty/10)] – [(% owner-occupied housing/10) + (% adults with college degree/10)]) / 4

Spatial access of on-premise and LBD-7 outlets distributes similarly across Baltimore City. Spatial access of LBD-7 outlets (mean SAI=20.4) was slightly higher than spatial access of on-premise outlets (mean SAI=18.4) or off-premise outlets (mean SAI=18.9) overall. Spatial access of on-premise and LBD-7 outlets tends to cluster along the I-83 corridor and Inner Harbor, though LBD-7 spatial access also extends into West Baltimore. The spatial access of on-premise (SAI 13.28 vs. 29.38, p<0.001) and LBD-7 outlets (SAI 16.80 vs. 28.01, p<0.001) was higher in areas where the residents were not predominantly African American (SAI 16.80 vs. 28.01, p<0.001 -- see Table 4-2). In contrast, off-premise outlet spatial access is high along the highway corridor that separates East and West Baltimore and two miles west of this corridor, and it is low along the Inner Harbor. These differences in how on-premise and LBD-7 outlets are distributed compared to off-premise outlets occur along economic lines. On-premise (SAI 29.06 vs. 16.99, p<0.001) and LBD-7 outlets (SAI 32.12 vs. 18.79, p=0.001) had higher spatial access in high-income areas while off-premise outlets had higher spatial access in low-income areas (SAI 23.84 vs. 17.82, $p<0.001$). On-premise and LBD-7 outlets were also less likely to have high access in areas of the most advantage or disadvantage. Of the four measures included in the social disadvantage index, on-premise outlets had higher access in areas with high education (SAI 25.25 vs. 11.15, $p<0.001$, data not shown), low poverty (SAI 24.38 vs. 16.47, $p<0.01$), and low percentages of female-headed households (SAI 33.11 vs. 13.80, $p<0.001$) but lower access in areas with high home ownership (SAI 13.77 vs. 20.04, $p<0.01$). LBD-7s had higher access in area with high education (SAI 23.19 vs. 14.88, $p<0.001$) and low percentages of female-headed households (SAI 29.61 vs. 17.34, $p<0.001$).

Table 4-2. Distribution of Spatial Accessibility Index of Alcohol Outlets by Community Demographics, Baltimore City, 2016 (n=599)

	On Premise[a]		Off Premise[b]		LBD-7[c]	
	Mean	t	Mean	t	Mean	t
African American						
50% or more (n=407)	13.28	6.66***	18.70	0.22	16.80	5.36***
Less than 50% (n=192)	29.38		19.26		28.01	
Low Income						
Less than $25,000 (n=105)	18.81	-0.23	23.84	-4.11***	22.55	-1.70
$25,000 or more (n=494)	18.36		17.82		19.94	
High Income						
$75,000 or more (n=126)	29.06	-3.79***	15.50	2.78**	32.12	-3.64***
Less than $75,000 (n=527)	16.99		19.34		18.79	
High Advantage on Index (<-3.77)						
Lowest quartile of index (n=151)	13.62	2.82**	16.54	2.65*	15.69	4.43***
Not lowest quartile of index (n=448)	20.06		19.67		21.98	
Low Advantage on Index						
Index at least 0 (n=152)	28.46	-5.30***	21.74	-1.19	26.21	-3.52***
Index less than 0 (n=447)	15.03		17.91		18.42	

[a]Calculated as the sum of the inverse distance to the 10 on-premise outlets nearest to the CBG centroid.
[b]Calculated as the sum of the inverse distance to the 10 off-premise outlets nearest to the CBG centroid.
[c]Calculated as the sum of the inverse distance to the 10 LBD-7 outlets nearest to the CBG centroid. LBD-7 outlets are bars/taverns that are permitted to sell alcohol for on- and off-premise consumption.

Table 4-3 presents results from the first linear regression model, which examined the association between access to all alcohol outlets and total violent crime exposure. In this regression, a 10% increase in the alcohol outlet SAI is associated with a 4.2% increase in total violent crime exposure (β=0.43, 95% CI 0.32, 0.54, $p<0.001$).

Table 4-3. Linear Regression Results for Violent Crime Exposure[a] by Total Alcohol Outlet Spatial Access

Variable	Model 1		
	β	95% CI	P Value
Total alcohol outlet SAI[b]	0.43	0.32, 0.54	<0.001
Drug arrests	0.07	0.01, 0.13	0.03
Percent African American	0.61	0.37, 0.85	<0.001
Median annual household income	-0.03	-0.06, 0.01	0.01
Owner-occupied housing	-0.04	-0.07, -0.02	<0.01
Population density	0.03	0.02, 0.03	<0.001
Moran's I	0.06		0.01

SAI Spatial accessibility index; SE Standard error; Moran's I Moran's Index
[a]Calculated as the sum of the inverse distance to the 62 violent crimes nearest to the CBG centroid.
[b]Calculated as the sum of the inverse distance to the 10 alcohol outlets nearest to the CBG centroid.

The results of models 2-4, which examine the association of types of outlets on total violent crime exposure, are presented in Table 4-4. Models 2-4 show that spatial access of the three types of alcohol outlets independently has a significant association with violent crime exposure. A 10% change in the on-premise SAI is associated with a 3.0% increase in total violent crime exposure (β=0.31, *95% CI* 0.20, 0.41, p<0.001). For off-premise outlets, a 10% increase in access is associated with a 4.4% increase in total violent crime exposure (β=0.45, *95% CI* 0.31, 0.59, p<0.001). While a 10% increase in LBD-7 access is associated with a 4.2% increase in total violent crime exposure (β=0.43, *95% CI* 0.32, 0.54, p<0.001). Model 5 considers all three types of alcohol outlets simultaneously. In this model, only access to off-premise (β=0.23, *95 CI* 0.07, 0.40, p<0.01) and LBD-7 outlets (β=0.36, *95% CI* 0.19, 0.52, p<0.001) remain significant. After adjusting for off-premise and LBD-7 spatial access, on-premise spatial access no longer has a significant association with total violent crime exposure (β=-0.0, *95% CI* -0.21, 0.11, p=0.54).

Table 4-5 presents results for models 6-9, which measure the association between three types of outlets on each type of crime separately. Model 6 shows that greater levels of off-premise (β=0.30, *95% CI* 0.15, 0.44, p<0.001) and LBD-7 spatial access (β=0.29, *95% CI* 0.15, 0.44, p<0.001) are associated with increased exposure to homicide. However, greater on-premise spatial access is not associated with homicide exposure (β=-0.12, *95% CI* -0.26, 0.01, p=0.08). The results from model 7 follow the same trend as model 6; off-premise (β=0.25, *95% CI* 0.07, 0.44, p=0.01) and LBD-7 spatial access (β=0.41, *95 CI* 0.23, 0.60, p<0.001) are associated with increased exposure to aggravated assaults while on-premise spatial access (β=-0.17, *95% CI* -0.35, 0.01, p=0.06) had no association. Model 8 shows that greater access to all three types of outlets is associated with greater sexual assault exposure (on-

Table 4-4. Linear Regression Results for Violent Crime Exposure[a] by Type of Alcohol Outlet Spatial Access, Baltimore City (n=599)

Variable	Model 2 On-Premise Outlets			Model 3 Off-Premise Outlets			Model 4 LBD-7 Outlets			Model 5 All Outlets		
	β	95% CI	P Value	β	95% CI	P Value	β	95% CI	P Value	β	95% CI	P Value
On-premise SAI[b]	0.31	0.20, 0.41	<0.001							-0.05	-0.21, 0.11	0.54
Off-premise SAI[c]				0.45	0.31, 0.59	<0.001				0.23	0.07, 0.40	<0.01
LBD-7 SAI[d]							0.43	0.32, 0.54	<0.001	0.36	0.19, 0.52	<0.001
Drug arrests	0.11	0.05, 0.17	<0.001	0.08	0.02, 0.15	<0.01	0.07	0.01, 0.13	0.03	0.05	-0.01, 0.11	0.10
Percent African American	0.60	0.34, 0.86	<0.001	0.27	0.05, 0.49	0.02	0.66	0.41, 0.90	<0.001	0.55	0.29, 0.81	<0.001
Median annual household income	-0.03	-0.06, 0.01	0.07	-0.04	-0.07, -0.01	0.03	-0.03	-0.06, 0.01	0.10	-0.03	-0.06, 0.01	0.06
Owner-occupied housing	-0.05	-0.08, -0.02	<0.01	-0.04	-0.07, -0.01	0.01	-0.05	-0.08, -0.02	<0.01	-0.04	-0.07, -0.01	0.01
Population density	0.03	0.02, 0.04	<0.001	0.03	0.02, 0.04	<0.001	0.03	0.02, 0.03	<0.001	0.02	0.02, 0.03	<0.001
Moran's I	0.07		<0.01	0.05		0.01	0.06		0.01	0.06		0.01

SAI Spatial accessibility index; SE Standard error; Moran's I Moran's Index

[a]Calculated as the sum of the inverse distance to the 62 violent crimes nearest to the CBG centroid.

[b]Calculated as the sum of the inverse distance to the 10 on-premise outlets nearest to the CBG centroid.

[c]Calculated as the sum of the inverse distance to the 10 off-premise outlets nearest to the CBG centroid.

[d]Calculated as the sum of the inverse distance to the 10 LBD-7 outlets nearest to the CBG centroid. LBD-7 outlets are bars/taverns that are permitted to sell alcohol for on- and off-premise consumption.

Table 4-5. Linear Regression Results for Violent Crime Exposure by Alcohol Outlet Spatial Access and Type of Outlet

Variable	Model 6 Homicide[a]			Model 7 Aggravated Assault[b]			Model 8 Sexual assault[c]			Model 9 Robbery[d]		
	β	95% CI	P Value	β	95% CI	P Value	β	95% CI	P Value	β	95% CI	P Value
On-premise SAI[e]	-0.12	-0.26, 0.01	0.08	-0.17	-0.35, 0.01	0.06	0.15	0.04, 0.26	0.01	0.07	-0.09, 0.23	0.41
Off-premise SAI[f]	0.30	0.15, 0.44	<0.001	0.25	0.07, 0.44	0.01	0.19	0.07, 0.30	<0.01	0.20	0.03, 0.37	0.02
LBD-7 SAI[g]	0.29	0.15, 0.44	<0.001	0.41	0.23, 0.60	<0.001	0.13	0.02, 0.25	0.02	0.28	0.11, 0.45	<0.01
Drug arrests	0.08	0.03, 0.14	<0.01	0.07	0.01, 0.14	0.04	0.04	-0.01, 0.08	0.07	0.03	-0.04, 0.09	0.44
Percent African American	1.11	0.87, 1.34	<0.001	0.73	0.43, 1.02	<0.001	0.31	0.13, 0.50	<0.01	0.32	0.04, 0.59	0.02
Median annual household income	-0.01	-0.04, 0.02	0.48	-0.04	-0.07, -0.01	0.03	-0.04	-0.06, -0.02	<0.01	-0.03	-0.06, 0.01	0.09
Owner-occupied housing	-0.06	-0.08, -0.03	<0.001	-0.06	-0.09, -0.02	<0.01	-0.03	-0.05, -0.01	<0.01	-0.01	-0.04, 0.02	0.38
Population density	0.02	0.01, 0.02	<0.001	0.03	0.02, 0.03	<0.001	0.01	0.01, 0.02	<0.001	0.02	0.02, 0.03	<0.001
Moran's I	0.07		0.01	0.04		0.05	0.11		<0.001	0.08		<0.01

SAI Spatial accessibility index; SE Standard error; Moran's I Moran's Index
[a]Calculated as the sum of the inverse distance to the 10 homicides nearest to the CBG centroid.
[b]Calculated as the sum of the inverse distance to the 30 aggravated assaults nearest to the CBG centroid.
[c]Calculated as the sum of the inverse distance to the 10 sexual assaults nearest to the CBG centroid.
[d]Calculated as the sum of the inverse distance to the 25 robberies nearest to the CBG centroid.
[e]Calculated as the sum of the inverse distance to the 10 on-premise outlets nearest to the CBG centroid.
[f]Calculated as the sum of the inverse distance to the 10 off-premise outlets nearest to the CBG centroid.
[g]Calculated as the sum of the inverse distance to the 10 LBD-7 outlets nearest to the CBG centroid. LBD-7 outlets are bars/taverns that are permitted to sell alcohol for on- and off-premise consumption.

premise β=0.15, *95% CI* 0.04, 0.26, p=0.01, off-premise β=0.19, *95% CI* 0.07, 0.30, p<0.01, LBD-7 β=0.13, *95% CI* 0.02, 0.25, p=0.02). The trends in model 9 mirrored those in models 6 and 7, with only off-premise (β=0.20, *95% CI* 0.03, 0.37, p=0.02) and LBD-7 spatial access (β=0.28, *95% CI* 0.11, 0.45, p<0.01) associated with greater exposure to robbery.

Conclusions

This analysis provides evidence that greater levels of spatial access to alcohol outlets in Baltimore City from 2012 to 2016 are significantly associated with increased exposure to violent crime, after controlling for neighborhood contextual factors. This conclusion is consistent with the previous analysis of alcohol outlet availability in Baltimore from 2005-2010 [219] as well as the literature from other large (>200,00 residents) cities in the US [70, 87, 90, 100, 121, 138, 145]. In Baltimore, a 10% increase in alcohol outlet access was associated with a 4.2% in exposure to violent crime. Sensitivity analyses show this is roughly equivalent to an increase in one additional outlet in a CBG is associated with an increase in about 12 violent crimes.

The association between alcohol outlets and violent crime depended on the type of outlet and the type of crime. Generally, off-premise and LBD-7 outlets appear to have a stronger association with violent crime than on-premise outlets do. For total violent crime, a 10% increase in off-premise outlet (4.4%) and LBD-7 (4.2%) spatial access had a stronger association than a 10% increase in on-premise spatial access (3.0%). Not only do neighborhoods that are low-income and predominately African American have higher access to alcohol outlets, but they also have greater access to the type of outlets associated with the most harm. However, trends in neighborhood context of alcohol outlet access in which alcohol outlets are located does not fully explain the associations between outlet type and violent crime, because on-premise and LBD-7 outlet access tends to be higher in similar types of neighborhoods, but LBD-7s are associated with more types of violent crime than on-premise outlets are. This suggests that the role of alcohol outlets in violent crime is complex and likely involves a combination of contextualizing factors and outlet characteristics.

Routine activity theory may help to explain the relationship between specific types of alcohol outlets and specific types of violent crime. Routine activity theory argues that homicide is an outcome rather than a type of crime, so homicides and aggravated assaults should be interpreted similarly [217]. The results of this analysis support this idea, because the trends in the associations between on-premise, off-premise, and LBD-7 outlets are similar for both aggravated assault and homicide. It is important to note that homicides and aggravated assaults do differ by choice of weapon. Eighty-three percent of the homicides during the study period were committed using a firearm (of the remaining homicides, 10% are committed with a knife and 7% with another type of weapon). In comparison, fewer aggravated assaults involve a firearm (28%). In these crimes, offenders also commonly use knives (24%), hands (12%), and other weapons (37%).

Distinguishing consensual and predatory crimes using routine activity theory may also help to explain the unique role of each type of alcohol outlet on violent crime exposure. Consensual crimes involve more than one offender (e.g., two young males who decide to fight each other), and predatory crimes involve a motivated offender who pursues a susceptible target (e.g., a teenager who snatches a passerby's purse). Aggravated assaults/homicides often have hallmarks of consensual crimes, while sexual assaults and robberies are generally predatory in nature. The mechanisms that promote and prevent consensual and predatory crimes differ. Place managers have a larger effect on preventing consensual crimes [217]. This is because offenders in consensual crimes may not be as concerned with witnesses so much as situational cues of order that signal whether they are likely to suffer consequences if they commit a crime.

The finding that off-premise and LBD-7 outlets are associated with aggravated assault/homicide may be the result of ineffective or lack of place managers at these outlets. Store clerks who oversee off-premise sales often work in solitary settings and may have an obstructed view of patrons, which decreases the chances of effective place management. People who purchase alcohol for off-premise consumption may then drink in public settings near the outlets (e.g., in abandoned lots or cars) where place managers are completely absent. In addition, the stronger associations with LBD-7s and total violent crime and aggravated assaults could stem from business hours; off-premise outlets must close by 12 midnight but LBD-7s can remain open until 2 AM. On the other hand, on-premise outlets often have several types of staff persons who can manage the environment and regulate patrons' consumption. In addition, on-premise outlets often regulate entrances with staff who check IDs, which can reduce the chances of motivated offenders entering the on-premise outlets in the first place.

In contrast, capable guardians can prevent predatory crimes [217]. In these situations, motivated offenders enter a space with a suitable target, but the crime doesn't occur until the potential guardians leave [217]. Routine activity theory suggests that the most common guardians are other people – they need not be security guards or police officers [217]. People often patronize off-premise outlets alone and pass through them quickly, decreasing the likelihood of encountering potential guardians. This lack of effective guardians could explain the finding that greater access to off-premise and LBD-7 outlets are associated with predatory crimes like sexual assaults and robberies. Unlike off-premise outlets, people tend to patronize on-premise outlets in groups. This means there are more people who could serve as potential guardians, and this presence of guardians could explain why greater access to on-premise outlets was not associated with increased exposure to robberies. There may also be fluidity in the guardian/offender role for sexual assaults whereby known acquaintances who might guard against robberies might also perpetrate sexual assaults. Approximately 8 out of 10 sexual assault victims knew the perpetrator [223].

The theoretical orientation and methods used to calculate alcohol outlet access and violent crime exposure are a strength of this analysis. In particular, previous work by study authors and others has shown that spatial access methods are more sensitive, precise, and stable than commonly-used counts of alcohol outlets and crime [158]. In addition, this analysis used CBGs instead of census tracts, which reduces aggregation bias by avoiding averaging across larger, more heterogeneous areas. Finally, this analysis coded off-premise and LBD-7 outlets separately to be able to tease apart the consequences associated with these distinct types of outlets. These methodological decisions all allowed the analysis to test different interpretations of routine activity theory.

The findings from this study are consistent with the majority of the literature that demonstrates a stronger association between off-premise outlets (compared to on-premise outlets) and violent crime [61, 79, 90, 94, 95, 122, 136, 138, 188, 198]. However, some elements of this analysis differ from previous studies. Unlike Gorman, Zhu, & Horel and Lipton & Gruenewald, this study found that access to on-premise alcohol outlets was associated with increased violent crime after adjusting for drug arrests [61, 188]. This difference could be attributable to using more sensitive methods to measure alcohol outlet spatial access.

This analysis has several limitations. First, the data obtained from the Baltimore City Liquor License Board contained minimal information. Thus, the analysis was unable to differentiate subtypes (beyond license category) of alcohol outlets, using data like volume of sales, area of floor space, hours of operation, and/or presence of a kitchen. These differentiations could be important because bars and restaurants likely have different associations with violence [156], and previous critiques emphasize the importance of isolating the effects of particular types of outlets

[69]. It is also possible that some outlets closed during the gap between data generation and analysis. Also, the BPD data only include crimes that were reported to the police. Greater percentages of robberies (62%) and aggravated assaults (62%) are reported to police than sexual assaults (32%) [224]. Thus, it is possible that there is underreporting in the dataset, though this underreporting is not anticipated to vary across CBGs. Finally, this is an ecological, cross-sectional study and cannot determine causality in isolation. One must consider the ecological fallacy, which states that findings at the population level might not generalize to the individual level. It is also possible that there are potential unmeasured confounder(s) that explain the association between alcohol outlet access and violent crime, although the analysis tried to incorporate commonly hypothesized ones such as income and social disadvantage. It is also possible that areas that have more crime attract alcohol outlets, a relationship that cannot be tested cross-sectionally.

Previous research concludes that limiting alcohol outlet density may prevent related harms [11]. The results of this analysis using routine activity theory suggest that limiting access to alcohol outlets or greater oversight of alcohol outlet operations may hold crime prevention potential. From a routine activity perspective, minimizing the impact of crime multipliers like alcohol outlets may have an exponential effect. Routine activity theory argues that criminal acts are themselves often crime multipliers because each crime requires, advertises, or escalates into another crime [217]. This means that communities hold the power to prevent crime by making criminal act more difficult, more risky, or less rewarding [217]. In the end, each prevented crime could translate into a series of prevented crimes. Future research should consider using longitudinal designs to determine whether limiting alcohol outlet access provide communities with multiplicative effects.

Chapter 5: The Violence Prevention Potential of Reducing Alcohol Outlet Access in Baltimore, MD

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Keywords: Alcohol, alcohol outlet density, violence, cost-effectiveness

Abstract

Background: Alcohol-related harms to others is an innovative frame that can inform policy decisions. Using the alcohol-related harms to others frame, this study determines the potential number of deaths and injuries averted, quality-adjusted life years (QALYs) preserved, and criminal justice costs saved from reducing alcohol outlet access in Baltimore.

Methods: This model builds on findings that each one-unit increase in spatial accessibility of alcohol outlets is associated with a 73.1% increase in violent crime. The cost-effectiveness analysis then examines four potential policies: 1) Reducing alcohol outlet access to the city median per census block group 2) Removing liquor stores in residential zones, 3) Removing bars/taverns operating as liquor stores, and 4) Removing both liquor stores in residential zones and bars/taverns operating as liquor stores.

Results: Reducing alcohol outlet access to the city median could prevent 2,175 crimes, save $57.8 million, and preserve 1,080 QALYs. Removing liquor stores in residential zones would prevent 416 violent crimes, save $35.1 million, and preserve 383 QALYs. Removing bars/taverns operating as liquor stores would prevent 320 crimes, save $19.1 million, and avert 188 DALYs. Removing both the liquor stores in residential zones and the bars/taverns operating as liquor stores would prevent 781 violent crimes, save $57.6 million, and preserve 608 QALYs.

Conclusions: This work links research to policy by quantifying potential benefits from reducing alcohol outlet access.

Background

Greater alcohol outlet access (i.e., the number and configuration of alcohol outlets in a geographic location) is associated with increased rates of violence [7, 12, 13, 180]. Researchers have consistently demonstrated the link between greater alcohol outlet access and higher rates of violent crime in cities across the United States like Baltimore, MD [137]; Washington, DC [59]; Cincinnati, OH [96]; Philadelphia, PA [95]; Minneapolis, MN [121, 145]; and New Orleans, LA [55] as well as suburban areas like Lubbock, TX [91], Bloomington, IN [134] and Norfolk, VA [189]. These results have also been replicated abroad in Canada [225], Finland [226], Sweden [227], Australia [14, 81-83, 99], and New Zealand [86]. There are sufficient data to warrant three systematic reviews [7, 12, 13], including several longitudinal designs [68, 78, 82, 85, 100, 189] and natural experiments that establish temporality [67, 87, 91, 184, 190]. If alcohol outlets caused violent crime, there should also be a gradient whereby greater exposure to alcohol outlets causes more crime and vice versa. Indeed, an analysis of the 1992 Los Angeles riots found that census tracts where alcohol outlets were burned during the rioting experienced reductions in violent crime, and those reductions were proportional to the number of alcohol outlets lost [87].

There are several key pathways through which alcohol outlets may cause crime. First, availability theory asserts that greater access to alcohol outlets expands physical availability, which drives price down [125]. This combination then increases consumption and related harms [125]. Second, social disorganization theory argues that alcohol outlets may undermine a neighborhood's ability to regulate and prevent violent crime. Thus, alcohol outlets attract people who establish an atmosphere of immoral or illegal behavior as well as young males (who are more prone to violence), regardless of whether those people are drinking [101, 142]. Lastly, routine activity theory asserts that alcohol outlets could have an environmental effect by bringing high-risk drinkers together and fostering opportunities for violence [7, 132].

Taken together, these data and theories form a strong case for a causal interpretation of the findings linking alcohol outlet access and violent crime. This lays the foundation for policy recommendations to limit access to alcohol outlets to reduce related harms. However, even in the face of these data, policymakers may want translational research to help integrate alcohol outlet access research into public policies. Holtgrave's Three Box Model provides a conceptual framework of four sets of under-utilized methods designed to bridge research and policy decision-making: systematic reviews and meta-analyses, decision analyses, multi-attribute utility analyses, and cost, cost-effectiveness, and cost-threshold analyses [228].

Systematic reviews and meta-analyses provide summaries of bodies of research that meet methodological standards. By documenting the trends in the literature, these condensed summaries can prevent researchers and policymakers from unknowingly relying on aberrant findings. The Guide to Community Preventive Services is an example of a key systematic review on alcohol outlet access with conclusions relevant to policymakers: "the regulation of alcohol outlet density may be a useful public health tool for the reduction of excessive alcohol consumption and related harms" [7]. Decision analyses are more specific than systematic reviews and meta-analyses. These analyses identify decisions of interest and then use data to quantify the consequences of each option. The lone example of a decision analysis related to the alcohol environment is Van Amsterdam et al.'s (2015) decision analysis comparing the levels of harm associated with different drugs to persons other than the drinker/user [229]. In this analysis, the components of harm were the "decisions" [229]. In the end, the authors concluded that alcohol is the drug with the most harms to persons other than the drinker/user [229]. Like decision analyses, multi-attribute utility analyses help with specific policy decisions. These analyses use ranking systems to prioritize different policy options, and the authors are unaware of any examples related to alcohol outlet access. Lastly, cost, cost-effectiveness, and cost-threshold analyses convert health-related events into dollar values. Once policies are converted to a fiscal scale, researchers can model and compare the anticipated outcomes associated with different policy options. To date, the authors are only aware of one cost-effectiveness analysis related to alcohol outlet access. Ahern et al. modeled how different alcohol outlet zoning policies would change levels of binge drinking in New York City [196]. The authors concluded that limiting alcohol outlet availability to 70 outlets per square mile would decrease binge drinking by 0.7% [196].

This lack of translational research means there is often a translation gap, whereby the results of alcohol outlet research cannot directly inform policy recommendations. Holmes et al. provide a detailed example of this translation gap, detailing the experience of liquor licensing in the United Kingdom (UK) [69]. In this example, policymakers attempted to enact evidence-based zoning decisions, but ultimately couldn't link routinely collected data on harms to specific outlets or groups of outlets [69].

The present study aims to address the translation gap by modeling the estimated consequences of various zoning policies that are based on the recent *TransForm Baltimore* initiative in Baltimore, MD. As a brief history, Baltimore initiated a zoning recode called "TransForm Baltimore" in 2007, which ended a 35-year stretch during which its zoning laws remained unchanged. The final bill included three provisions related to alcohol outlet zoning: 1.) require liquor stores located in residential zones to amortize (i.e., relocate or change the nature of their business) over a 2-year period, 2.) require LBD-7s (i.e., bars/taverns, which function as both on- and off-premise outlets and are the most common license type in Baltimore) to demonstrate substantial floor space and sales devoted to on-site consumption, and 3.) ban new liquor stores from opening within 300 feet of existing liquor stores (except downtown). The present study calculates the cost of alcohol-attributable violent crime in Baltimore in 2016 and compares four policy options to reduce alcohol outlet access: 1) reduce off-premise alcohol outlet access to the city median (this is a hypothetical policy designed to model the maximum impact), 2) close the 80 liquor stores in residential zones, 3) close the 117 "sham" bars/taverns (i.e., alcohol outlets with a LBD-7 bar/tavern license that operate as a liquor store), and 4.) close both the 80 non-conforming liquor stores and the 117 "sham" bars/taverns.

Methods

Overview

This was an ecologic analysis using publicly available data from Baltimore City. The data on homicides, aggravated assaults, rapes, and robberies from 2016 (n=11,909) were from the Baltimore City Police Department (BCPD) and all alcohol outlets (n=1,218) as of July 2016 were from the Board of Liquor License Commissioners.

Measures

Geographic Units

U.S. census block groups (CBGs) were used as the primary geographical unit of analysis in this study. There are 653 CBGs in Baltimore. The population in Baltimore CBGs ranges from 0 to 4,828 people, and there are on average three CBGs per census tract.

Violent Crime

Victim-based violent crime data was obtained from BCPD via OpenBaltimore [204]. Violent crimes include homicide, aggravated assault, rape, and robbery. In 2016, there were 11,909 violent crimes (318 homicides, 285 rapes, 5,557 robberies, and 5,749 aggravated assaults). The violent crime data were geocoded by BCPD.

Alcohol Outlets

Liquor license information, including license type and address, was obtained from the Board of Liquor License Commissioners as of June 2016. In 2016, there were 1,218 alcohol outlets in Baltimore City. There are 14 license types with a range of restrictions on days/hours of sales and types of products that may be sold. Eleven license types are for on-premise consumption: AE (adult entertainment), D (brewery), LB (restaurant beer/wine/liquor), LBAL (arena), LBHM (hotel/motel), LC (non-profit club beer/wine/liquor), LD (bar/tavern beer/wine/liquor), LMZ (zoo), WB (restaurant beer/wine), WC (private/non-profit club beer/wine), WD (tavern beer/wine). Two license types are off-premise: LA/LA-2 (package stores beer/wine/liquor) and WA (package stores beer/wine). The last license type is unusual. The LBD-7 has the longest opening hours (6AM-2AM) and most days of sales (7), and license holders are permitted to both serve alcohol on-premise and to sell package goods for off-premise consumption. It is the most common license type in Baltimore City (n=421). The analysis was able to match 1,211 (99%) of the alcohol outlets in ArcGIS.

Non-Conforming Liquor Stores

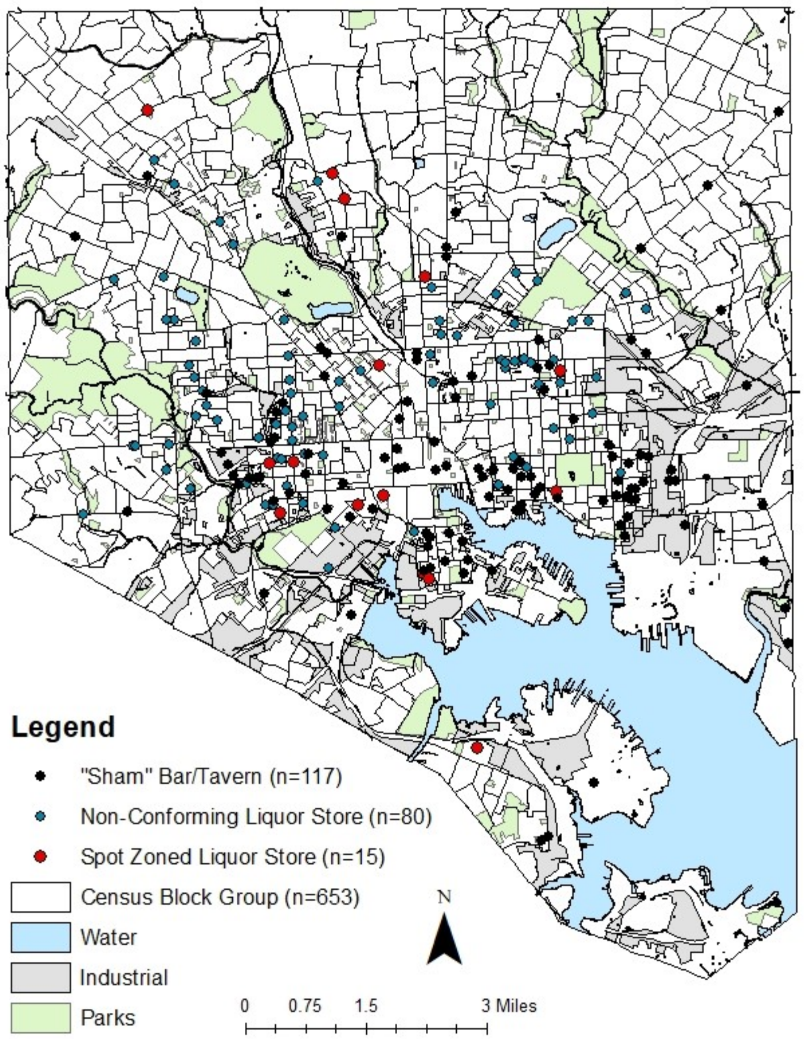
Non-conforming liquor stores are off-premise alcohol outlets with license types LA, LA-2, and WA located in residential neighborhoods. The Citizen's Planning and Housing Association identified 105 non-conforming liquor stores in 2013, and 95 of these remained in 2016 [230]. During the *TransForm Baltimore* discussions, 19 non-conforming liquor stores were spot zoned, meaning they will need to relocate under the new zoning code. Researchers were able to obtain information for 15 of these 19 outlets, and the cost-effectiveness analyses did not amortize these known spot zoned outlets. Thus, there were a total of 80 non-conforming liquor stores included in the cost-effectiveness analysis (see Figure 5-1).

"Sham" Bars/Taverns

"Sham" bars/taverns are alcohol outlets with a LBD-7 (bar/tavern) license operating as an off-premise outlet. This is problematic, because LBD-7 licenses have more lenient operating hours than off-premise licenses.

TransForm Baltimore mandates all alcohol outlets with a LBD-7 license must devote at least 50% of their sales floor and sales to on-premise consumption to ensure they are not operating as an off-premise outlet. "Sham" LBD-7s were identified using an alcohol outlet assessment tool, which documented the percentage of the sales floor devoted to on-premise consumption; data on volume of sales were unavailable. Alcohol outlets with a LBD-7 license and less than 50% of the sales floor devoted to on-premise consumption were designated as "sham" bars/taverns. There were 117 "sham" bars/taverns in 2016 (see Figure 5-1).

Figure 5-1. Non-Conforming Liquor Stores and "Sham" Bars/Taverns in Baltimore, 2016



Association between Alcohol Outlet Access and Violent Crime

This study used a measure of association from recent analyses the count of violent crime as a function of the access of alcohol outlets [231]. Briefly, recent analyses by the study authors used BCPD data from 2012-2016 and liquor license data as of July 2016. Violent crimes included homicide, aggravated assault (including non-fatal shootings), rape, and robbery. The analyses adjusted for high density of alcohol outlets, count of vacant houses (as a measure of disorganization), percent African American population, median annual household income, percent of population aged 18-35 years, and count of drug arrests. The measure of association used spatial accessibility indices (SAIs), where higher values indicate greater access. The SAI was calculated by summing the inverse network distances from the CBG centroid to each of the 25 closest alcohol outlets. This SAI was then log transformed. Access ranged from 9.13 to 644.71 with an average of 54.53. Each one-unit increase in the natural log of the SAI was associated with an 73.1% increase in the number of violent crimes (*IRR*=1.731, *95% CI* 1.582, 1.894, $p<0.001$).

Statistical Analyses

Alcohol-Attributable Fractions

Alcohol-attributable fractions (AAFs) are the proportion of outcomes that are causally attributable to alcohol [232]. There are two types of outcomes: those that are 100% attributable to alcohol (i.e., the outcome never occurs without alcohol) and those where a fraction of the cases is attributable to alcohol. Violent crimes fall into the latter category. This study used AAFs calculated by Bouchery, Simon, and Harwood (2013). Briefly, Bouchery, Simon, and Harwood estimated AAFs for excessive drinking following the *Guidelines for Cost of Illness Studies in the Public Health Service* [233]. The team produced AAFs for fatal and non-fatal outcomes for each condition related to alcohol consumption. They used the Centers for Disease Control and Prevention's Alcohol-Related Disease Impact Tool's AAFs for fatal outcomes (e.g., homicide), which is based on the perpetrator's alcohol consumption [4]. For non-fatal crimes, Bouchery, Simon, and Harwood first determined the prevalence of offenders who report consuming alcohol prior to the type of crime using national surveys (e.g., Survey of Inmates in State and Federal Correctional Facilities). They then attributed 50% of violent crimes and 10% of property crimes for which offenders reported being under the influence of alcohol as alcohol-attributable [233].

Cost-Effectiveness Analysis

A cost-effectiveness approach was then used to model the number of crimes and burdens (cost and disability-adjusted life years) alcohol outlet access zoning could avert from a societal perspective. This analysis used the natural log of the SAI from the previous analysis by study authors. Thus, the analysis determined the natural log of the SAI for each CBG at baseline [$\ln(SAI_B)$] for each policy. The analysis then determined the natural log of the SAI that would exist under the new policy [$\ln(SAI_N)$]. These methods varied by policy, as described below.

Each one-unit increase in the natural log of the SAI is associated with an 73.1% increase in violent crime (*95% CI* 58.2%, 89.4%). Thus, the complement proportion reduction in violent crime (R) was calculated assuming a multiplicative model using the formula below. This process was repeated using the lower and upper limits of the 95% confidence interval from the measure of association between alcohol outlet SAI and violent crime to generate confidence intervals for the cost-effective analyses.

$$R_N = \left[[\frac{1}{1.731}]^{\ln(SAI)_N} \right]$$

This model simplifies to the following:

$$R_N = \frac{1}{{SAI_N}^{0.55}}$$

After calculating the natural log of the SAI that would exist under the policy, the number of crimes (C) that would occur under the new policy was calculated as the number of violent crimes in 2016 for the CBG multiplied by the complement of the percent reduction in the violent crime for the policy:

$$C_N = V*(1-R_N)$$

To determine the number of crimes averted, the difference (D_N) between the 2016 BCPD reports (V_N) and the calculated number of crimes (C_N) was determined:

$$D_N = V-C_N$$

This process was repeated, using a slightly different method depending on the policy, as outlined below.

Policy 1: City Median. Reducing alcohol outlet access to the city median was selected as the maximum possible effect. The median was selected over the mean, because there were several outliers that increased the mean (e.g., Downtown/Seton Hill has 7.8 alcohol outlets per 1,000 population). In Baltimore in 2016, the median SAI was 41.12 [ln(41.12)=3.72]. For the policy 1 that reduced the city to the median, the analysis subtracted the natural log of the median SAI [$\ln(SAI_M)$] from the baseline natural log of the SAI if the baseline SAI was greater than the median. Otherwise, the cost-effectiveness analysis set the value for the new natural log of the SAI to the current natural log of the SAI.

$$\ln(SAI)_{N1} = \ln(SAI)_B - \ln(SAI)_M \text{ if } \ln(SAI)_B > \ln(SAI)_M$$

$$\ln(SAI)_{N1} = \ln(SAI)_B \text{ if } \ln(SAI)_B \leq \ln(SAI)_M$$

Policy 2: Amortize Non-Conforming Liquor Stores. For policy approach 2 that amortized the 80 non-conforming liquor stores that were not spot zoned, $\ln(SAI)_L$ was set to the difference of the natural log of the baseline SAI rate and the natural log of the SAI that would exist if the non-conforming outlets [$\ln(SAI)_{N2}$] were removed from the CBG:

$$\ln(SAI)_{N2} = \ln(SAI)_B - \ln(SAI)_L$$

Policy 3. Amortize “Sham” Bars/Taverns. Similar to policy approach 2, policy approach 3 that amortized the 117 “sham” bars/taverns, $\ln(SAI)_N$ was set to the difference between the natural log of the baseline SAI and the natural log of the SAI that would exist if the “sham” bars/taverns [$\ln(SAI)_S$] were removed from the CBG:

$$\ln(SAI)_{N3} = \ln(SAI)_B - \ln(SAI)_S$$

Policy 4. Amortize Non-Conforming Liquor Stores & “Sham” Bar/Taverns. Policy 4 combines policy 1 and 2 to amortize the 80 non-conforming liquor stores and 117 “sham” bar/taverns simultaneously. In this approach, $\ln(SAI)_N$ equaled the difference between the natural log of the baseline SAI and the natural log of the SAI that would exist if the non-conforming liquor stores and “sham” bar/taverns were removed from the CBG [$\ln(SAI)_C$]:

$$\ln(SAI)_{N3} = \ln(SAI)_B - \ln(SAI)_C$$

The tangible costs per crime were derived from McCollister et al. (2010). Briefly, the authors used a two-step approach to determine the cost-per-crime using a societal perspective. First, the authors used a cost-of-illness method, and then they used a jury compensation method [234]. This data source was selected because it was from the US, was nationally representative, used a societal perspective, and contained most of the same crime categories as the BCPD data [234]. This study only used direct costs, which include direct victim costs (i.e., medical costs, property/cash losses, and lost earnings), criminal justice system costs (i.e., police costs, adjudication costs, and corrections costs), and career crime costs (i.e., lost earnings for perpetrators) [234]. However, one limitation of these data is they were from 2008 [234]. Therefore, these data were adjusted using the Consumer Price Index from 2008 dollars to 2016 dollars (CPI=1.106).

The disability-adjusted life years (DALY) per crime were derived from Dolan et al (2005) as a measure of intangible cost-per-crime. Briefly, the authors combined data from two sources to determine the physical and psychological effects of crime. First, the authors used the British Crime Survey to determine the frequency of physical injuries by type of crime and the Global Burden of Disease Study to determine the duration and weight of injuries [235]. Then, the authors used existing literature to determine the likelihood, duration, and weight of acute stress disorder and post-traumatic stress disorder by type of crime [235]. The authors used the injury duration and weights to determine health losses for each crime, using a 3.5% discounting rate [235].

Sensitivity Analysis

This analysis included a sensitivity analysis to account for concerns about causality between alcohol outlet access and violent crime. This sensitivity analysis included one threshold at 50%. That is, this analysis assumed that 50% of the association between alcohol outlet access and violent crime was causal. This reduction in violent crime was calculated as follows:

$$R_S = \left[\frac{1}{{SAI_N}^{0.55}}\right]/2$$

Results

Alcohol-Attributable Violence

Alcohol was estimated to be responsible for 3,391 violent crimes in Baltimore in 2016 (see Table 5-1). Of these, robbery (n=1,472) and aggravated assault (n=1,690) were the most common. However, homicide (n=149) was the most severe, as is indicated by having the largest associated costs. The costs associated with the alcohol-attributable crimes amounted to $289.8 million, most of which was from homicides ($213.7 million). Using the Census estimated population for Baltimore in June 2016, alcohol-attributable violence cost $471 per Baltimore resident [236].

Table 5-1. Number of Alcohol-Attributable Crimes, Associated Costs (in Millions), and Associated DALYs in Baltimore, 2016

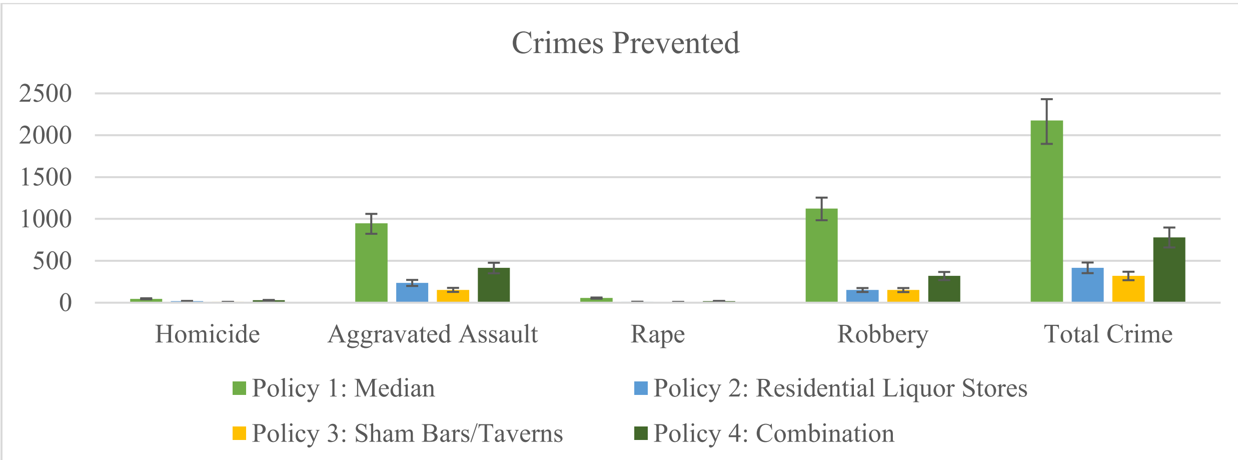
	Homicide	Aggravated Assault	Rape	Robbery	Total
Number of crimes[a]	318	5,749	285	5,557	11,909
Alcohol-attributable fraction[b]	47.0	29.4	28.3	26.5	–
Number of alcohol-attributable crimes[c]	149	1,690	80	1,472	3,391
Cost per crime[d]	$1,434,392	$21,921	$46,279	$24,009	–
Alcohol-attributable cost of crime (in millions)[e]	$213.7	$37.0	$3.7	$35.3	$289.8
DALY per crime[f]	17.79	0.191	0.561	0.028	–
Alcohol-attributable DALYs[g]	2,650.7	322.8	44.9	41.2	3,059.6

DALY = Disability-adjusted life year
[a]Data are from 2015 Baltimore City Police Data.
[b]Alcohol-attributable fractions are the proportion of crimes that are attributable to alcohol and include federal & state incarceration costs.
[c]Calculated as the number of crimes*alcohol attributable fraction.
[d] From McCollister, K.E., French, M.T., & Fang, H. 2010. Adjusted from 2008 dollars to 2016 dollars using a consumer price index of 238.1/212.2/=1.122
[e]Calculated as the number of alcohol-attributable crimes*2016 cost per crime
[f]From Dolan, P., Loomes, G., Peasgood, T., & Tsuchiya, A. 2005.
[g]Calculated as the number of alcohol-attributable crimes*DALY per crime

Alcohol Outlet Access Policy Potential Impacts on Violence

The average proportion reduction in violent crime under the median policy was 25.1% among the 326 CBGs that would experience a reduction (*95% CI* 21.7%, 28.2%, data not shown). This strategy would avert 2,175 violent crimes (*95% CI* 1,897, 2,431), save $115.5 million from a societal perspective (*95% CI* $103.4m, $129.9m), and prevent 1,080 DALYs (*95% CI* 324, 441) (see Figure 5-2). Closing non-conforming liquor stores reduced alcohol outlet access in 438 CBGs, which reduced violence by an average of 6.0% (*95% CI* 5.0%, 6.9%). This policy would avert 416 violent crimes (*95% CI* 353, 480), save $35.1 million dollars (*95% CI* $29.6m, $40.3m), and prevent 383 DALYs (95% CI 324, 441). Closing the "sham" bars/taverns reduced alcohol outlet access in 564 CBGs and translated to an average of 2.8% (*95% CI* 2.3%, 3.2%) reduction in violent crime. This policy would prevent 320 violent crimes (*95% CI* 269, 370), save $19.1 million (*95% CI* $16.7m, $22.1m), and prevent 188 DALYs (*95% CI* 136, 218). The combined policy of closing both the non-conforming liquor stores and the "sham" bars/taverns reduced the alcohol outlet access in 599 CBGs by an average of 7.4% (*95% CI* 6.3%, 8.5%). This policy would prevent 781 violent crimes (*95% CI* 660, 898), save \$57.6 million (*95% CI* \$48.7m, \$66.2m), and prevent 608 DALYs (*95% CI* 516, 699).

Figure 5-2. Crimes averted, costs saved, and QALYs preserved by four proposed alcohol outlet access policies



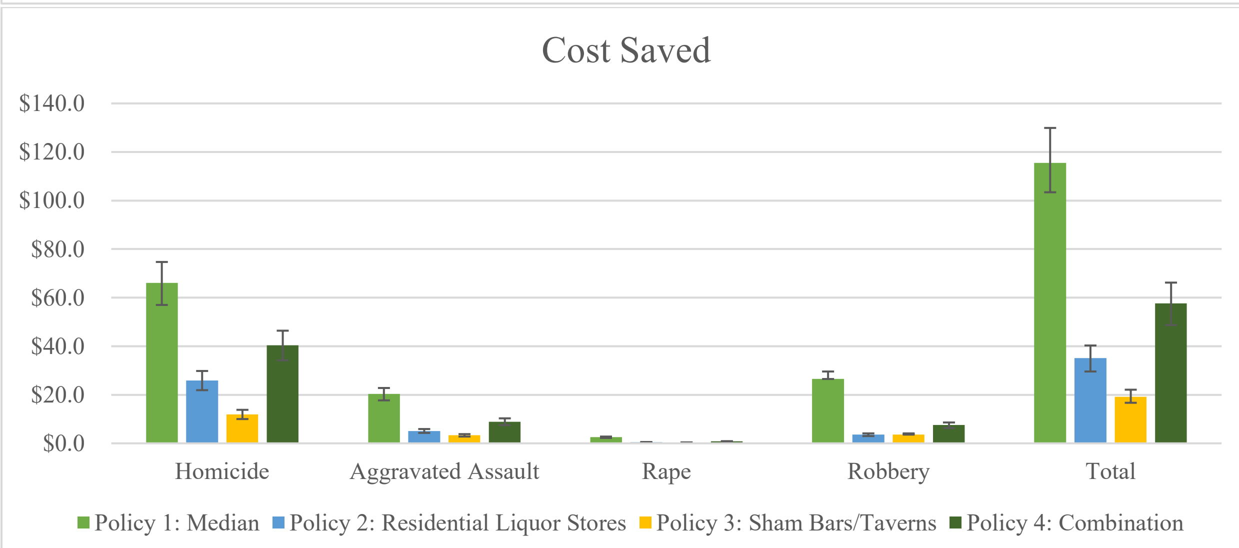
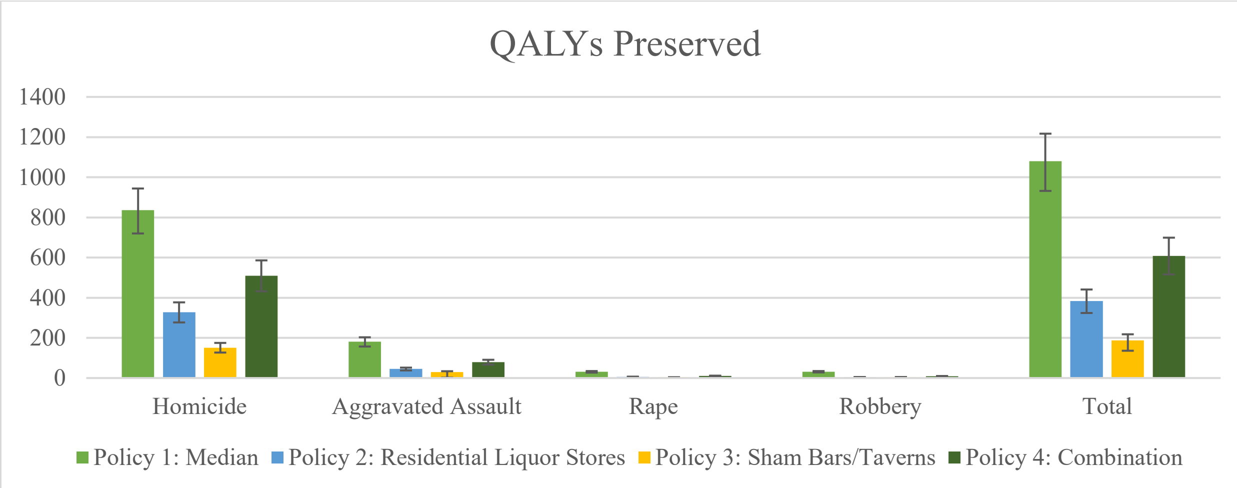


Figure 5-2. Crimes averted, costs saved, and QALYs preserved by four proposed alcohol outlet access policies (continued)



NOTE: Cost estimates are from McCollister, K.E., French, M.T., & Fang, H. 2010. Calculated as number of crimes averted*cost provided in McCollister et al (2010) adjusted to 2016 dollars (see Table 5-1). DALY estimates are from Dolan, P., Loomes, G., Peasgood, T., & Tsuchiya, A. 2005. Calculated as number of crimes averted*DALY estimate in Dolan et al (2005) (see Table 5-1)

Sensitivity Analysis

The number of crimes that could be prevented by decreasing alcohol outlet access to the city median would decrease from a maximum value of 2,175 if the association was 100% causal to 1,088 if the association was 50% causal (data not shown). This could still save Baltimore $57.8 million and prevent 589 DALYs. Closing the non-conforming liquor stores prevented more crimes (280), saved more money ($17.6m), and averted more DALYs (192) than closing the "sham" bars/taverns did (160, $9.6m, and 94, respectively). The combination of closing both non-conforming liquor stores and "sham" bars/taverns would prevent 391 crimes, save $28.8 million, and avert 304 DALYs if the association between alcohol outlet access and violence was 50% causal.

Discussion

There is an ongoing violence epidemic in Baltimore, with recent years breaking records for number of homicides (343 in 2017, 318 in 2016, 344 in 2015). This study suggests that alcohol could play a role in the current violence, with almost a third of violent crime attributable to excessive drinking. Costs for the alcohol-attributable portion of violent crime were also significant ($289.7 million), exceeding the city budget for police patrol, which was $248.0 million in fiscal year 2016 [237].

There is substantial potential to prevent violent crimes by reducing alcohol outlet access in Baltimore City. The combination of closing the non-conforming liquor stores and "sham" bars/taverns is the recommended strategy. While reducing alcohol outlet access in each CBG to the city median would obtain the largest results, this is likely to be politically infeasible due to large profits associated with downtown areas or entertainment zones. This policy was intended to illustrate the upper bound of savings through reducing alcohol outlet access in Baltimore ($125.1 million); however, even this would be unable to offset the substantial costs of alcohol-attributable violence in Baltimore.

Of note, these are conservative estimates in many ways. The cost estimates exclude intangible costs (e.g., the victim's pain and suffering) and they exclude costs borne by persons other than the victim (e.g., friends and family). In addition, all estimates were rounded down to the nearest number of full crimes prevented. Thus, the true financial impact of alcohol outlet access reduction could be larger than is modeled here.

This study has several limitations. Firstly, this analysis was unable to model relocating the non-conforming liquor stores and "sham" bars/taverns, because analysts were unsure where or whether they will reopen. In this sense, the analysis may overestimate the potential results of alcohol outlet zoning. In addition, it is possible that amortizing the non-conforming liquor stores and "sham" bars/taverns might actually increase the disparities. Alcohol outlets tend to cluster in low-income and minority neighborhoods [59, 238], and alcohol outlet access zoning would ideally aim to reduce the concentration of outlets in these neighborhoods. Legally, Baltimore is unable to revoke a liquor license, as it is private property. This is why *TransForm Baltimore* will relocate instead of close alcohol outlets. However, many available, affordable buildings are in low-income, high-minority neighborhoods. Therefore, the ideal implementation of the policies outlined in this paper require supports to incentivize moving displaced outlets to low-density, low-crime neighborhoods to prevent increasing physical availability of alcohol in already disadvantaged neighborhoods.

This study used cost data that are almost 10 years old. While the analysis utilized consumer price indices to adjust the estimates for inflation, it is possible that the cost structure of violent crime has evolved during the past decade. However, the cost estimates were calculated using rigorous methods and only included direct costs. Accurate cost estimates can be used to demonstrate the disproportionate burden of alcohol-related harms, which can craft compelling policy arguments [239]. Therefore, public health researchers should update estimates of costs of violent crime from a societal perspective to inform policy debates.

Lastly, the DALY estimates were from a 2005 study in the United Kingdom. While the authors of this study used more rigorous methods to generate these DALY estimates, it is possible that frequency of physical injury from violent crime differs in the US and the United Kingdom and severity from violent crime in the US from the global estimates. Therefore, researchers should also aim to update estimates of DALYs for violent crime to facilitate comparisons of policy proposals across public health domains.

Still, this analysis demonstrates the substantial burden of alcohol-attributable crime on Baltimore City and the potential opportunities to prevent violent crimes inherent in alcohol outlet access zoning policies. Quantifying these burdens and benefits is anticipated to support evidence-based policy decisions.

Chapter 6: Conclusions

Alcohol-attributable violence is a significant public health problem. It is more common than drink driving crashes in the United States (US) [212]. Every day, there are 43 homicides in the US, and excessive drinking (e.g., binge drinking, heavy drinking) is responsible for 20 of them [4]. Alcohol's disinhibiting effects increases the risk of perpetrating violence [3, 213, 240]. In addition, alcohol increases the risk of violence victimization, making people less physically or mentally likely to resist an attack [241]. Two out of five homicide victims test positive for alcohol [214], and women who average six or more drinks per day are more likely to become sexual assault victims [215]. All of these associations mean that alcohol-attributable violence carries a large price tag; crimes that result from excessive drinking cost the US an estimated $36.7 billion in 2010 [216].

When it comes to alcohol-related violence, environments matter. Numerous studies show that greater access to alcohol outlets is associated with increased rates of violence [14, 52, 58, 61-63, 65-68, 70-101] as well as other harms like traffic crashes [41, 66, 77, 106-111], sexually transmitted infections [112], and child abuse and neglect [60, 116-118]. Thus, alcohol environments are a significant social determinant of health (SDOH) -- a condition in which people live, work, and age that influences important health outcomes [242]. As such, "upstream" factors like alcohol environments have important potential for advancing individual and population health.

By focusing on SDOH, public health also has an opportunity to advance health equity, because many SDOH are distributed unevenly. This is the case with alcohol outlets; they often cluster in low-income and African American neighborhoods [31, 59, 159, 243-245]. These inequalities in the SDOH manifest as health disparities -- systemic and avoidable differences in health where disadvantaged groups have worse outcomes [246]. Of note, violence is itself a health disparity, as victims of violence are disproportionately low-income and/or African American [203, 247] and have heightened risk for future health harms like ischemic heart disease, cancer, stroke, and chronic obstructive lung disease [248]. A focus on SDOH and health disparities is an opportune approach, because two of the overarching goals of Healthy People 2020 are to even the distribution of SDOH and combat health disparities [249].

Another strategic way to view alcohol-attributable violence is through the lens of alcohol-related harm to others (H2O) -- harms attributable to alcohol that occur via social behavior, social interactions, or social settings, independent of the drinking of the victim of those harms [250]. These "secondhand" harms comprise a cutting-edge area of research that has not received the same scrutiny as harms suffered directly by drinkers. In fact, alcohol is the drug with the most related harms borne by persons other than the drug user [251]. This means H2O research has exciting potential for documenting additional burdens due to excessive alcohol use. This perspective offers enhanced justification for population-level measures such as alcohol policies. In addition, it can help to counter neo-liberal objections to those policies because people often view restrictions on individual liberties as more acceptable if they are protecting innocent victims.

Given this background, this dissertation rests at the intersection of H2O and health disparities. The three analyses focus on Baltimore City, which is an ideal setting for studying the interplay between these two concepts, because it has both high levels of alcohol-related harms and stark inequalities. From 2011-2015, drug and alcohol intoxication were directly responsible for 4.5% of all deaths in Baltimore [252]; however, this leaves out the main other causes of death in which alcohol is a factor, such as intentional and unintentional injury, cancer, heart disease, liver cirrhosis, and so on. Nearly half (46%) of the alcohol-related emergency department admissions in MD from 2008-2014 occurred in Baltimore even though it only contained 10% of the state's population in 2014 [236, 253]. One potential reason for the higher rates in Baltimore is that persons who are low-income or African American experience greater alcohol-related harms at lower levels of consumption, a well-documented health disparity [254]. Baltimore is 62% African American, and 19% of households (and 34% of children) live below the federal poverty level [255]. As a result of these and other disparities, life expectancies can differ by as much as 20 years across neighborhoods [210]. Yet alcohol outlet density is rarely considered by city leaders to be a factor in these disparities.

Alcohol-attributable violence is a particularly timely H2O to study in Baltimore, because Baltimore is currently experiencing a homicide epidemic. The number of homicides has been breaking records for the last several years (343 in 2017, 318 in 2016, 344 in 2015). In 2016, Baltimore had 1,780 violent crimes per 100,000 residents, which puts it on par with Detroit, Michigan (2,046), Saint Louis, Missouri (1,903), and Memphis, Tennessee (1,820) [203]. Given these trends, there is currently substantial focus on how to prevent violent crime.

In order to reach defensible conclusions about these pressing problems, this dissertation began with the notion that accurate measurement is paramount. Measurement aims to map real-world phenomena to numerical representations [256]. It is a process that requires a clear understanding of the specific construct(s) that the measurements will capture. Following on the literature review in Chapter 2 summarizing the current research and measurement practices regarding alcohol outlet density and related harms, and drawing from other public health areas, Chapter 3 is the first analysis of the alcohol environment to clearly define and compare what the three most common methods of quantifying the alcohol environment are actually measuring. Traditional count-based methods measure availability, which is the number of existing alcohol outlets that people could patronize. Proximity measures accessibility, which is how easy or hard it is to get to an alcohol outlet. Lastly, spatial access methods measure spatial access, which is the combined effect of availability and accessibility. Of these techniques, only spatial access measures are capable of detecting clustering [156], which is important for understanding the level of harms that are associated with distributions of alcohol outlets [160, 220]. This explanation provides a necessary foundation for selecting appropriate measurement methods, because public health researchers can only improve their methods when they know what they are seeking to measure. As a foundation for the analysis in Chapter 3, the literature in Chapter 2 highlights an essential disconnect between common conceptualizations and methods used in the field: the majority of the field seeks to measure alcohol outlet density but they use count-based methods that actually measure alcohol outlet availability [11, 12, 14, 56, 58, 76, 81-86, 88, 92-95, 97, 105, 108, 109, 121, 127-130, 145, 155, 157, 170, 172-183]. These distinctions have significant real-world implications, as alcohol outlet availability, spatial access, and density have different policy implications. Availability policies would only be concerned with limiting the number of stores that serve alcohol in an area. From such a standpoint, these stores could be located anywhere. On the other hand, zoning policies that regulate alcohol outlet spatial access or density would seek to prevent or minimize clusters of alcohol outlets from occurring and would be concerned with both the number and location of the outlets.

Public health researchers must evaluate the accuracy of their measurements in order to determine their reliability, validity, and possible sources of error. This is a critical enterprise, because poor measurement can render research findings open to question. The analysis presented in Chapter 3 compares three common measurement methods and shows that the method used most frequently contains the highest levels of error. Counts systematically misclassify areas. For example, counts labeled large areas with several alcohol outlets along their boundary as having high access while the proximity and spatial access methods did not. In addition, the regression residuals from the count-based models had the widest range, which indicates a greater level of error. Lastly, the count-based models produced variables that were not log-normal. For the linear regression models, this often meant that the linearity assumption was not met. This added additional error, because assuming linearity in the face of non-linear data will systematically yield inaccurate predictions.

Chapter 3 concludes that proximity measures are more accurate than the count-based methods, but less stable. In other words, the proximity calculations contained high levels of random error. Despite this limitation, proximity methods overcame many limitations from counts, including eliminating edge effects, aggregation bias, and the modifiable areal unit problem. In the end, Chapter 3 concludes that proximity methods are simple to calculate, requiring only two data points, and offer reasonably accurate measurements.

However, the spatial access method is the measurement technique that appears to have the lowest levels of random and systematic error. These methods consistently had the lowest Akaike's information criteria value, because they explained the most variance with the greatest parsimony. These methods smoothed over areas to produce accurate and stable estimates in locations with few alcohol outlets. In addition, these methods captured high density areas well, provided that the choice set size was sufficiently large. As choice set sizes increased to model these dense areas, the spatial access methods were also likely to detect clustering, decreasing the need for a separate variable that indicates areas where alcohol outlets are highly dense.

These findings in Chapter 3 set the stage for Chapters 4 and 5. Chapter 4 extends the findings from Chapter 3 by implementing the spatial access methods to determine how alcohol outlet access relates to violent crime in Baltimore City. The main findings in Chapter 4 are that greater access to alcohol outlets is associated with higher levels of exposure to violent crime, and outlets that permit sales for off-site consumption play a larger role than those that only allow patrons to drink inside the outlet. A 10% increase in alcohol outlet access was associated with a 4.6% increase in violent crime exposure, which roughly equates to one alcohol outlet and 12 violent crimes.

Chapter 4 also goes one step further to investigate the distribution of alcohol outlets by type of outlet and type of crime. As is consistent with a SDOH and health disparities lens, Chapter 4 showed that the types of alcohol outlets associated with the most harms (off-premise outlets) are more accessible in disadvantaged areas. In these analyses, access to all types of alcohol outlets was lower among the areas with the most social advantage. This suggests that the most privileged neighborhoods have the lowest access to alcohol outlets across the board, and their residents consequently have the lowest risk for harms from high alcohol outlet density. Among the remaining neighborhoods, alcohol outlets distribute along lines of social advantage, and this distribution differs by type of outlet. Areas with higher advantage (i.e., higher median annual household incomes, low unemployment, few female-headed households, low poverty, and higher home values) and fewer African American residents are more likely to have higher access to on-premise alcohol outlets, which have the weakest association with violence. On the other hand, areas with the least advantage (i.e., low median annual household income, low home ownership, high unemployment, high percent of female-headed households, high percentages of households living in poverty, and low home values) and higher percentages of African American residents are consistently more likely to have higher access to off-premise outlets, which have the strongest association with violent outcomes. These trends suggest that disadvantaged areas have higher access to all alcohol outlets, but in particular they have greater access to the types of alcohol outlets associated with the most harms.

Access to off-premise and LBD-7 outlets was strongly associated with exposure to all four types of violent crime – homicide, aggravated assault, sexual assault, and robbery. In contrast, access to on-premise outlets was associated with increased exposure to sexual assault and decreased exposure to homicide and aggravated assault. Access to on-premise outlets was unrelated to robbery exposure after adjusting for off-premise and LBD-7 access. Chapter 4 explains these trends using routine activity theory to examine outlet characteristics and alcohol consumption. Ultimately, chapter 4 argues that effective place managers (e.g., store clerks, waitresses) are a determining factor for homicide and aggravated assault while capable guardians (e.g., bystanders who would be witnesses) prevent sexual assaults and robbery. Outlets that predominantly sell alcohol for off-site consumption tend to have less effective place managers and capable guardians. On the other hand, on-premise outlets have a wider variety of potential place managers (e.g., bartenders, waitresses, disc jockeys, bouncers) and more capable guardians because people often patronize on-premise outlets in groups. Chapter 4 argues that increased access to on-premise outlets is associated with increased exposure to sexual assault because there is fluidity in the role of guardians for sexual assault; someone who may guard against robbery may also perpetrate sexual assaults.

In order to address the “translational gap” identified in Chapter 2 and demonstrate the potential of policies that address H2O and SDOH, Chapter 5 translates the findings from the previous two chapters into a format that is useful for public health officials. The H2O angle of this research is noteworthy. H2O research is the analog to secondhand smoke research, which played a key role in marshalling attention and resources to tobacco policy change, and H2O research is similarly strategically poised to garner support for alcohol policies. People who experience H2O are more likely to support alcohol policies [257], which suggests that greater awareness of H2O might help foster public support for effective alcohol policies. In addition, having recent and detailed prevalence estimates of H2O makes it possible to generate more accurate estimates of the total burden of alcohol on society. This information could then justify increasing resources for combatting alcohol-related harms, to make the level of resources more commensurate with alcohol's burden to society. In line with this, Chapter 5 establishes the burden of H2O in Baltimore City using alcohol-attributable fractions. This analysis found that excessive drinking was responsible for nearly 12,000 violent crimes in Baltimore in 2016 (318 homicides, 5,749 aggravated assaults, 285 sexual assaults, and 5,557 robberies). These violent crimes cost Baltimore taxpayers $289.8 million.

The policies included in the cost-effectiveness analysis in Chapter 5 aim to balance effectiveness and acceptability. Public support is often least supportive of restrictions on bars and restaurants. These popular outlets are untouched by the three main policy proposals, because Chapter 4 showed that these on-premise outlets have weak associations with violent outcomes. However, off-premise and LBD-7 outlets (i.e., outlets that must devote at least 50% of their floor space to on-site consumption and are permitted to sell both on- and off-premise) have strong associations with violent crime, and are the foundation for the three focused proposals for reducing access to potentially hazardous outlets: 1) Removing non-conforming liquor stores (i.e., liquor stores in residential zones) 2) Removing "sham" bar taverns, which are LBD-7 outlets that do not devote sufficient floor space to on-premise sales, and 3) Removing both non-conforming liquor stores and "sham" bar/taverns. When comparing the effects of these policy options, the analysis concludes that the combined strategy would yield the largest benefits. It would prevent 781 violent crimes, save $57.6 million, and preserve 608 quality-adjusted life years each year.

In order to understand how the measurement methods from Chapter 3 affect the results presented in Chapter 5, sensitivity analyses were performed. These analyses show that the choice of measurement technique has significant consequences for the inferences. If the spatial access methods are replaced with count-based methods, the number of crimes that could be prevented dropped to between 1% and 12% of the original estimates (263 vs. 2,175 for the median policy, 6 vs. 416 for the non-conforming liquor stores, 40 vs. 320 for the "sham" bar taverns, 54 vs. 781 for the combined strategy). These sensitivity analyses are one final example of the insensitivity of the count-based methods, but they also demonstrate the significance of the work presented in Chapter 3. Public health proposals based on insensitive methods may be unrealistic.

Linking back to the health disparities theme, Chapter 5 ends with a cautionary note that alcohol outlet zoning strategies must consider equitable distribution of alcohol outlets when relocating particularly harmful outlets. Many of the city's available land parcels are located in less advantaged areas, which means that alcohol outlet zoning efforts that aim to reduce inequitable distribution of SDOH could actually end up shuffling alcohol outlets from one disadvantaged area to another. In the end, this may actually exacerbate the disparities public health aims to fix.

The health disparities angle of Chapters 4 and 5 is important because there are compelling justice and economic reasons for eliminating those disparities. Social justice advocates argue that disparities must be eliminated because they further reduce already disadvantaged groups' likelihood of attaining equal footing [258]. This means that health equity-based arguments can draw on values of equality, nondiscrimination, and fairness [258]. From a practical standpoint, health disparities do not just burden the disadvantaged groups, they limit improvement in the overall system and increase system costs.

In conclusion, this dissertation combines rigorous methodological investigation with the compelling frames of H2O and health disparities. In doing so, Chapter 3 presents the first analysis to provide conceptual guidance on common alcohol outlet density measurement techniques by comparing their performance in a regression setting. This chapter concludes that the count-based methods used in the majority of the alcohol outlet density research to date are prone to error and that spatial access methods provide a more accurate alternative. Chapter 4 extends this work by investigating the role of alcohol outlets in violent crimes using the most advanced measurement techniques available. The findings from this chapter explore the distribution of SDOH in Baltimore, which is likely fueling health disparities. Chapter 5 then leverages the H2O frame to present the first cost-effectiveness analysis that examines the violence prevention potential of alcohol outlet density zoning policies.

If there is a single take-away point from this dissertation, it is that alcohol outlets are a significant feature of the built environment, posing a substantial barrier to the elimination of health disparities. Both in the interests of reducing health disparities, and for the purpose of better assessing the burden of alcohol on communities and promoting commensurate distribution of resources and regulation, accurate and scientifically-valid measurement of the implications of alcohol outlet access for public health should become a routine feature of public health surveillance.

Appendix A: Detailed Methods Appendix

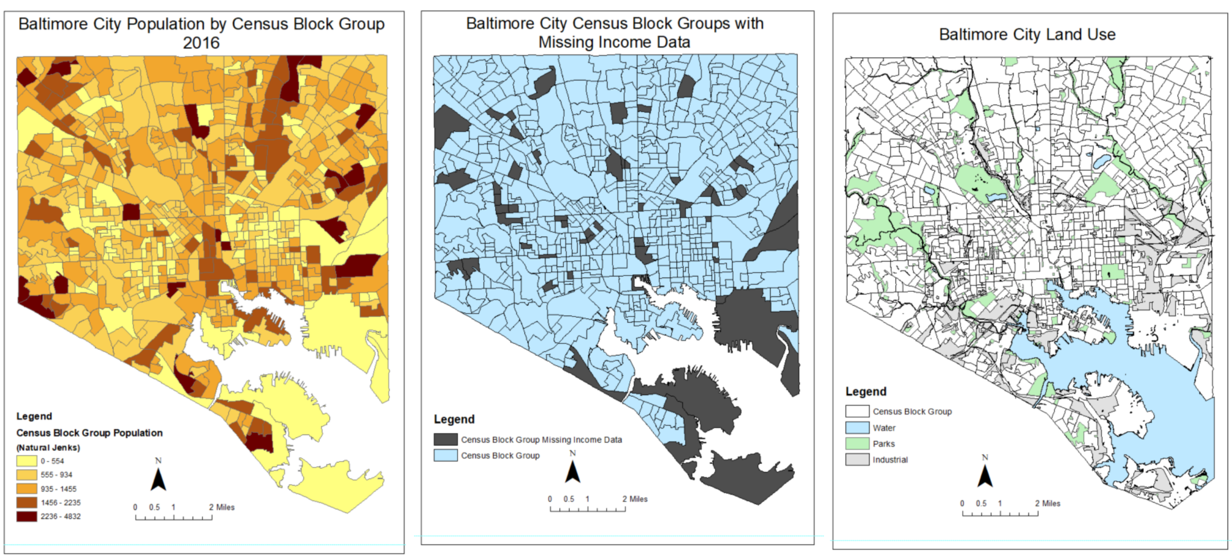
General Information

Baltimore Census Block Groups

There are 653 census block groups (CBGs) in Baltimore (see Figure A-1). CBGs in Baltimore contain between 0 and 4,832 people, and there are on average three CBGs per census tract.

Fifty-four CBGs were missing income data. CBGs with missing income data often contain large portions of industrial areas. They are also more likely to have lower populations (982 vs. 627, t=3.58, p<0.001) and lower spatial access to alcohol outlets (15.98 vs. 11.27, t=2.42, p=0.02). The CBGs with missing income data do not differ from the other CBGs in terms of number of alcohol outlets (t=-0.58, p=0.56), proximity to the nearest alcohol outlet (t=-0.10, p=0.92), percent African American residents (t=-1.27, p=0.21), number of drug arrests (t=-0.33, p=0.74), or social disorder (t=0.60, p=0.55).

Figure A-1. Demographics of Baltimore City



Alcohol Outlet Data

Liquor license information, including license type and address, was obtained for 1,218 alcohol outlets from the Board of Liquor License Commissioners for 2016. Liquor license information was current as of July 4, 2016. There are 14 license types with a range of restrictions on days/hours of sales and types of products that may be sold (see Table A-1). Fourteen licenses were dropped due to limited days of sales or lack of location (Pimlico Race Track [1], Baltimore Zoo [1], arenas [7], and municipal [5]). The remaining 1,204 licenses were categorized as on-premise, off-premise, or LBD-7 (both on- and off-premise) based on license type.

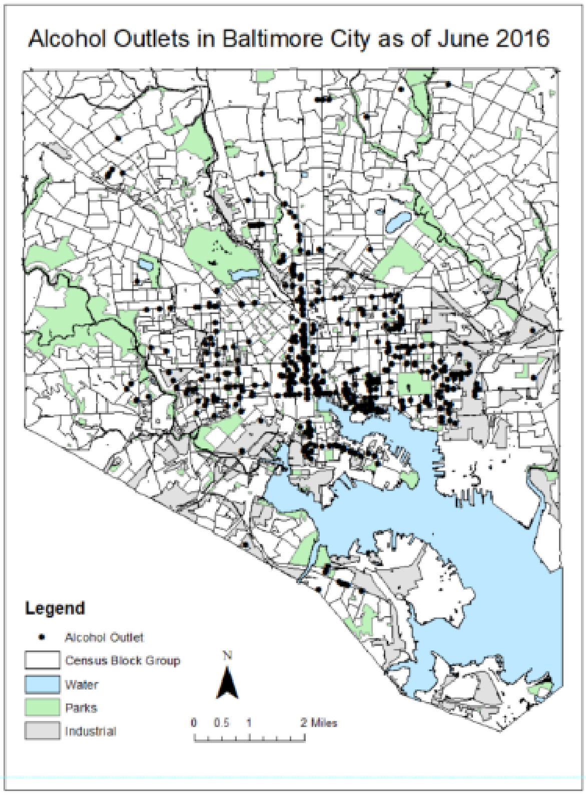
The addresses for these 1,204 outlets were geocoded using an address locator in ArcGIS and StreetMap 2013. About half of the outlets (603) did not have a 100% match score, mostly owing to formatting of street directions (589). The remaining 14 licenses had new or incorrectly entered street addresses. Researchers used other resources (e.g., Google Maps) to confirm the location and assign coordinates to these remaining outlets.

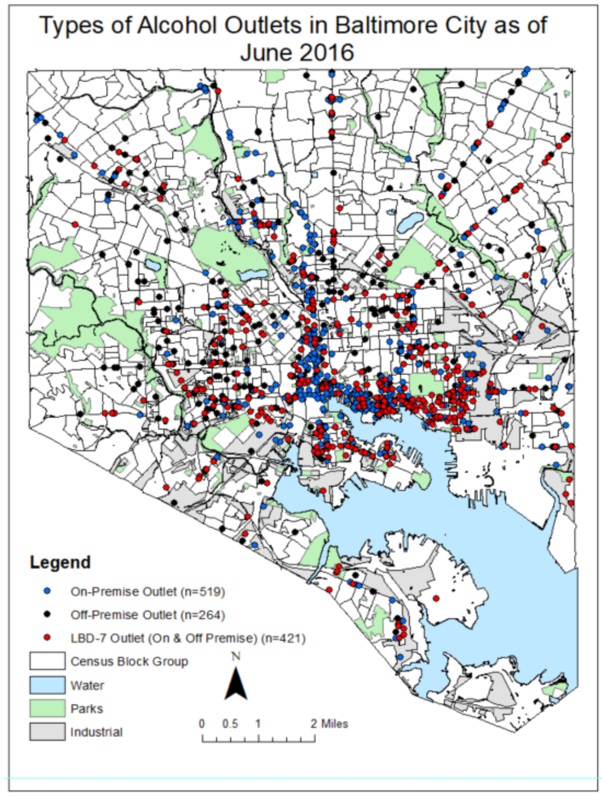
Table A-1. Alcohol Outlet License Types in Baltimore City

License Type	Description	Days	Hours	Count
On-Premise				
AE	Adult entertainment	7	6 AM-2 AM	25
D	Breweries	Limited	Limited	3
LB	Beer/wine/liquor restaurant	7	6 AM - 2 AM	298
LBHM	Hotel/motel	7	6 AM - 2 AM	25
LC	Beer/wine/liquor private/non-profit clubs	7	6 AM - 2 AM	47
LD	Beer/wine/liquor bar/tavern	7	6 AM - 2 AM	51
WB	Beer/wine restaurants	7	6 AM - 2 AM	14
WC	Beer/wine private/non-profit clubs	7	6 AM - 2 AM	13
WD	Beer/wine taverns	7	6 AM - 1 AM	43
Off-Premise				
WA	Beer/wine package stores	6	6 AM - 12 midnight	30
LA	Beer/wine/liquor package stores	6	6 AM - 12 midnight	234
Both On- and Off-Premise				
LBD-7	Beer/wine/liquor bar/tavern with package stores	7	6 AM - 2 AM	421

The following maps illustrate the distribution of outlets in Baltimore. Outlets tend to cluster along the I-83 corridor (i.e., the vertical line that separates east and west Baltimore) and along the Inner Harbor.

Figure A-2. Distribution of Alcohol Outlets in Baltimore City, 2016





Methods for Chapter 3

Measures

Alcohol Outlet Access Variables

This study calculated alcohol outlet access using three separate methods: counts, proximity, and spatial access methods.

Counts. This study used the spatial join tool in ArcGIS to count the number of alcohol outlets located in each CBG. Several studies discuss the best method for weighting the counts of alcohol outlets [55, 83, 87, 159]; however, there is no clear consensus on the relative merits of each denominator choice [69]. The analysis used a raw count and three of the most common types of weights: population, area, and total roadway miles [69].

$$Y_i = \frac{x_i}{w_i}$$

Where:

Y = Container-based alcohol outlet availability

X = Number of alcohol outlets

W = Weight (population, square miles, or total roadway miles)

i = Census block group

Proximity. This analysis used the closest facility network analyst function in ArcGIS to calculate the distance-based variables. In particular, the analysis determined the shortest network distance from each CBG centroid to the closest alcohol outlet as a measure of travel impedance.

$$Y_i = \min(d_i)$$

Where:

Y = Distance-based alcohol outlet accessibility

d = Network distance to nearest alcohol outlet

i = Census block group

Spatial Access. This study also used the closest facility network analyst tool to calculate the network distance to the seven alcohol outlets closest to each CBG centroid to make up an alcohol outlet "choice set." Consumers consider up to seven plus or minus two options when making choices or evaluating settings, and this logic has been applied to decisions in analysis of access to parks, shopping locations, alcohol outlets, and others (see Zhang, Lu, & Holt, 2011, for discussion) [184, 185, 208]. Also of note, the "choice set" approach does not require defining containers, so it avoids edge effects. After defining the "choice set," the SAI was calculated by summing the inverse distances from the CBG centroid to each of the seven closest alcohol outlets.

$$Y_i = \sum_1^7 \frac{1}{d}$$

Where:

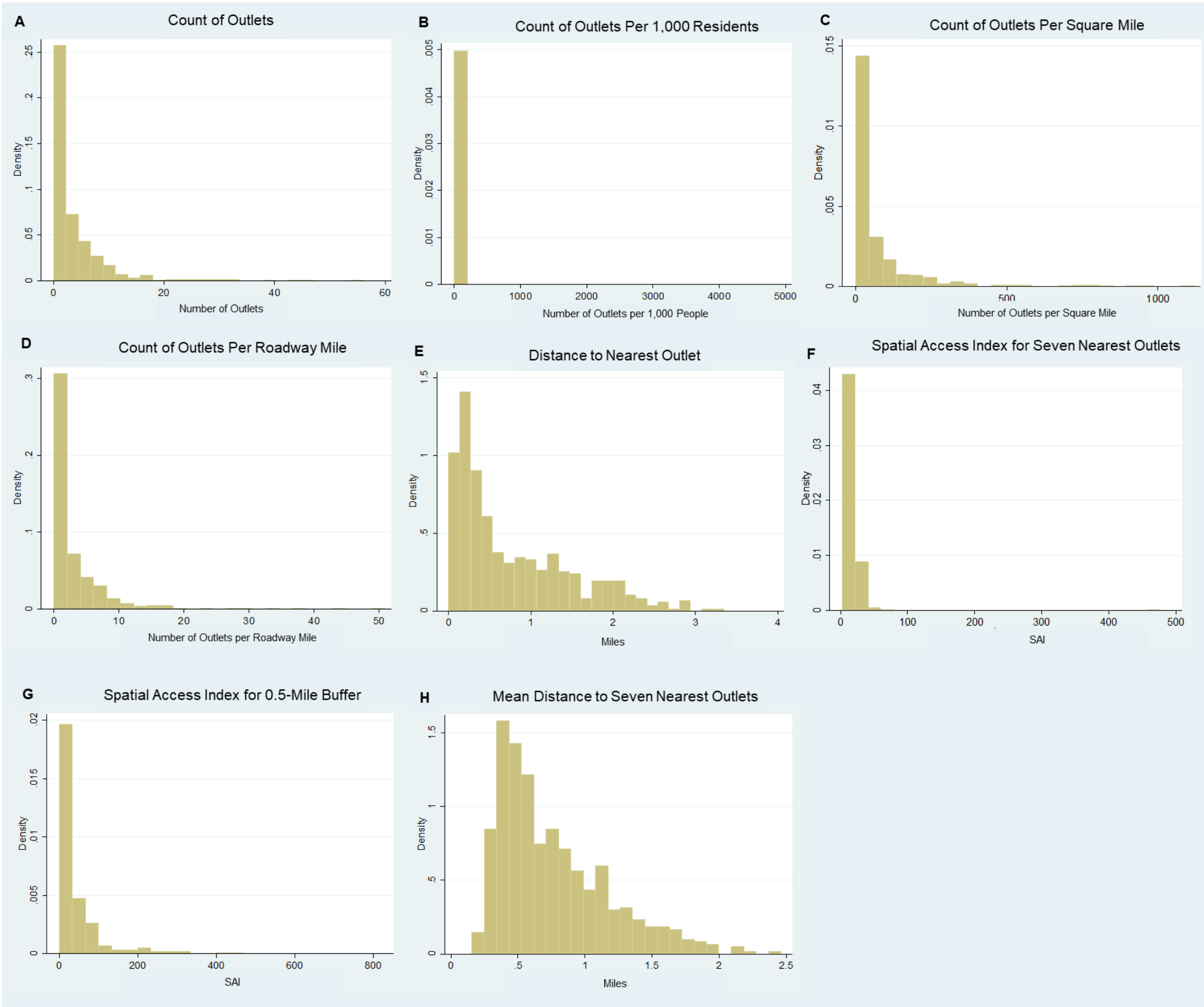
Y = Alcohol outlet spatial access

d = Network distance to the next nearest alcohol outlet

i = Census block group

Figure A-3 below illustrates the distribution for the alcohol outlet variables used in Chapter 3. All of the variables are heavily right skewed, but the proximity (E) and mean distance to the seven nearest alcohol outlets (H) are the least skewed.

Figure A-3. Histograms of Alcohol Outlet Access Variables



As shown in Figure A-4, the natural log transformations produced approximately normally distributed variables for proximity (D), the SAI with seven nearest outlets (E), and the mean distance to the seven nearest outlets (G). The variables that used a container (A-C, F) were not log-normal.

Figure A-4. Quantile-Normal Plots of Natural Log-Transformed Measures of Alcohol Outlet Access

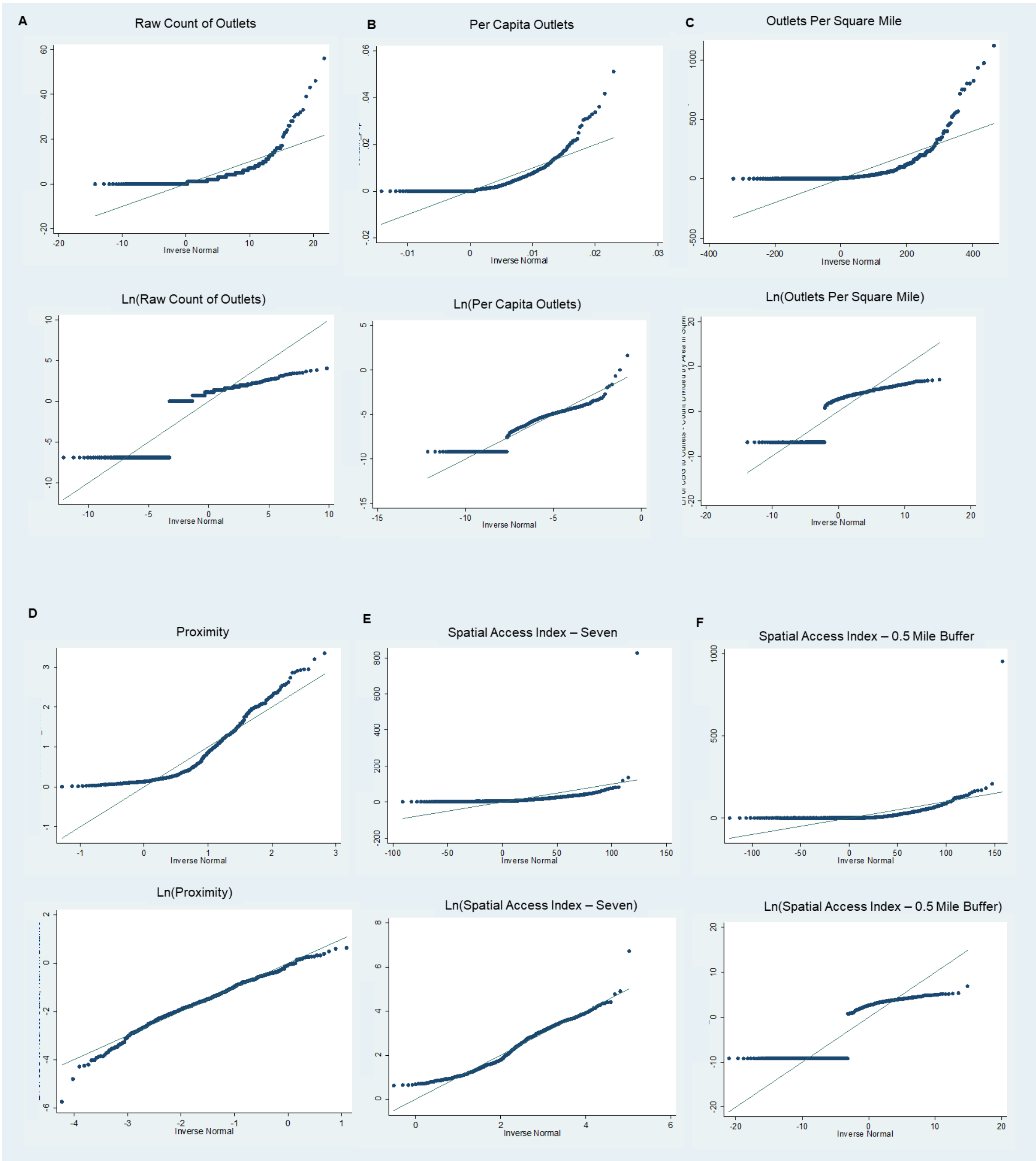
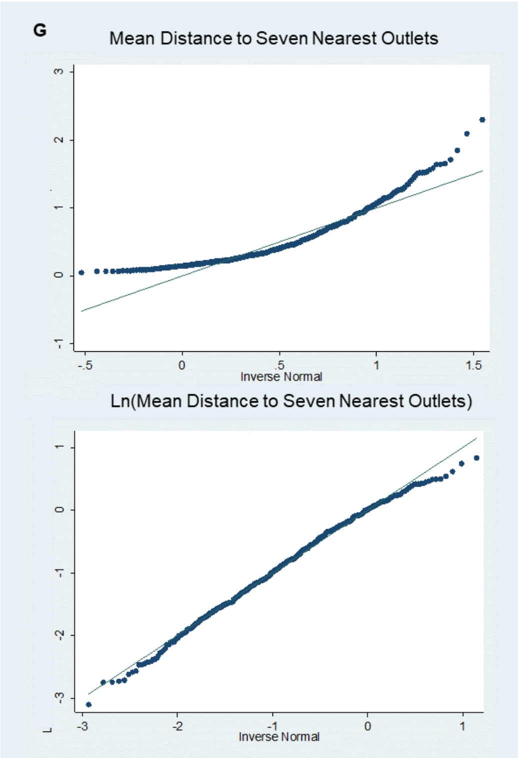


Figure A-4. Quantile-Normal Plots of Natural Log-Transformed Measures of Alcohol Outlet Access (Continued)



Violent Crime Variables

This study also calculated violent crime exposure using three separate methods: count, proximity, and spatial access methods.

Counts. This study used the spatial join tool in ArcGIS to count the number of violent crimes that occurred in each CBG. The analysis did not weight violent crime by population because the negative binomial regression uses the natural log of population as the offset.

$Y_i = X_i$

Where:

Y = Container-based violent crime

X = Number of violent crimes

i = Census block group

Proximity. The analysis used the same methods to calculate violence proximity and alcohol outlet proximity.

Spatial Access. This study used the same methods to calculate the spatial access of violent crimes and alcohol outlets.

Figure A-5 shows the histograms of the violent crime exposure variables used in Chapter 3. All of these variables were highly right skewed, though the proximity (A) and SAI variables using a choice set (B) were roughly log normal. Although the container-based violent crime had fewer 0 values than the container-based alcohol outlet access variables in Figure A-3, it resulted in a variable that was still not log-normal (see Figure A-6).

Figure A-5. Histograms of Violent Crime Variables

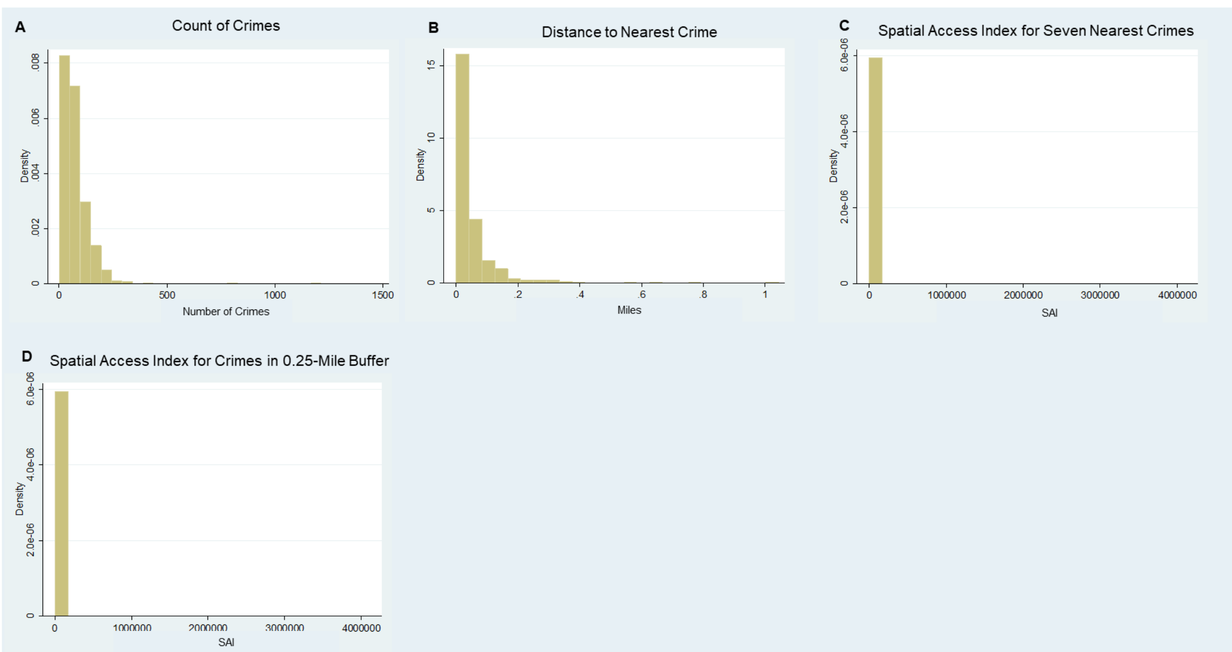


Figure A-6. Quantile-Normal Plots of Natural Log-Transformed Measures of Violent Crime

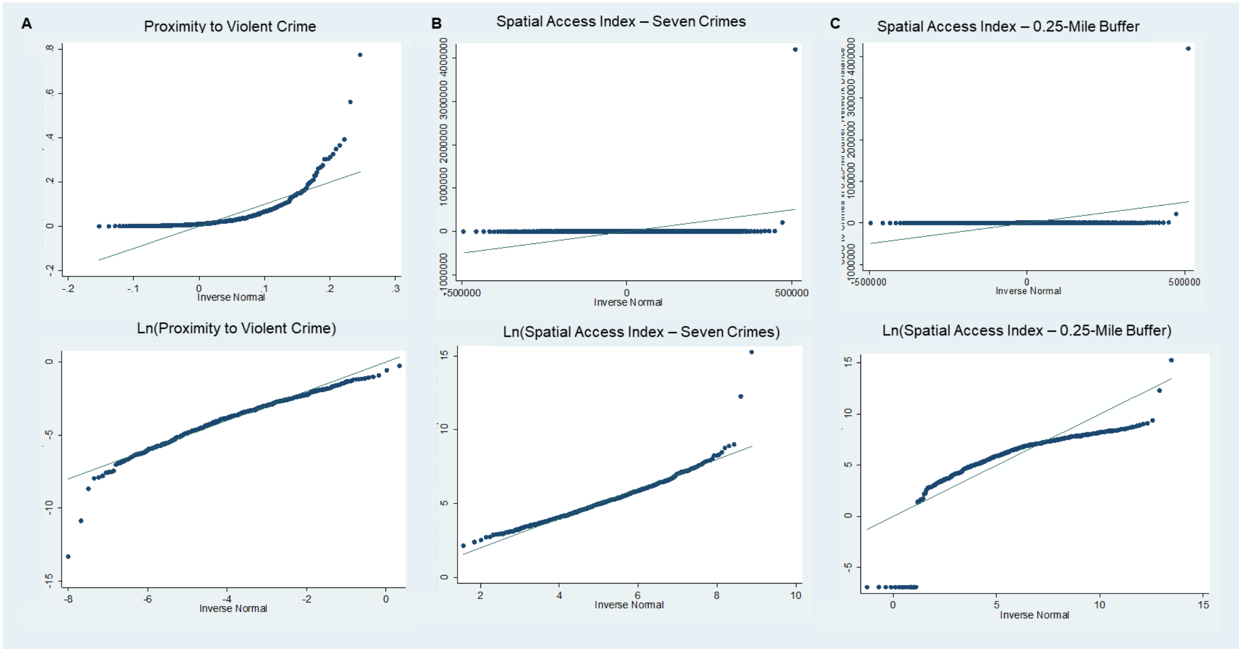
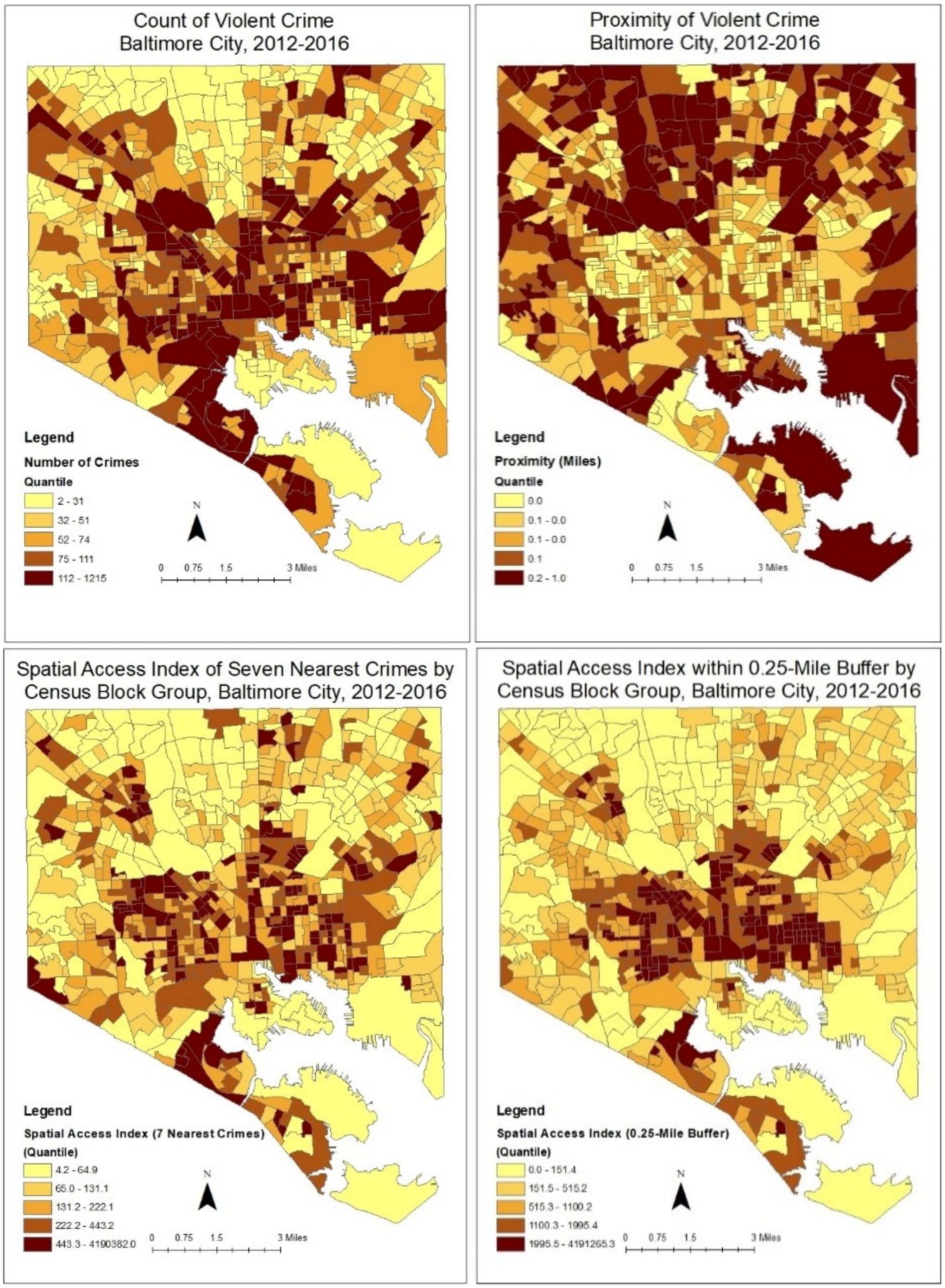


Figure A-7 shows the distribution of the violent crime exposure variables by CBG. Of all the specific crimes, homicide exposure is the most concentrated. Homicides cluster along the edge of industrial areas in West Baltimore, particularly in CBGs approximately two miles west and northwest of downtown Baltimore. Assault, rape, and robbery exposure tend to concentrate in the city center, with aggravated assaults and rapes having slightly higher exposure in South Baltimore and robbery having greater exposure along the Inner Harbor.

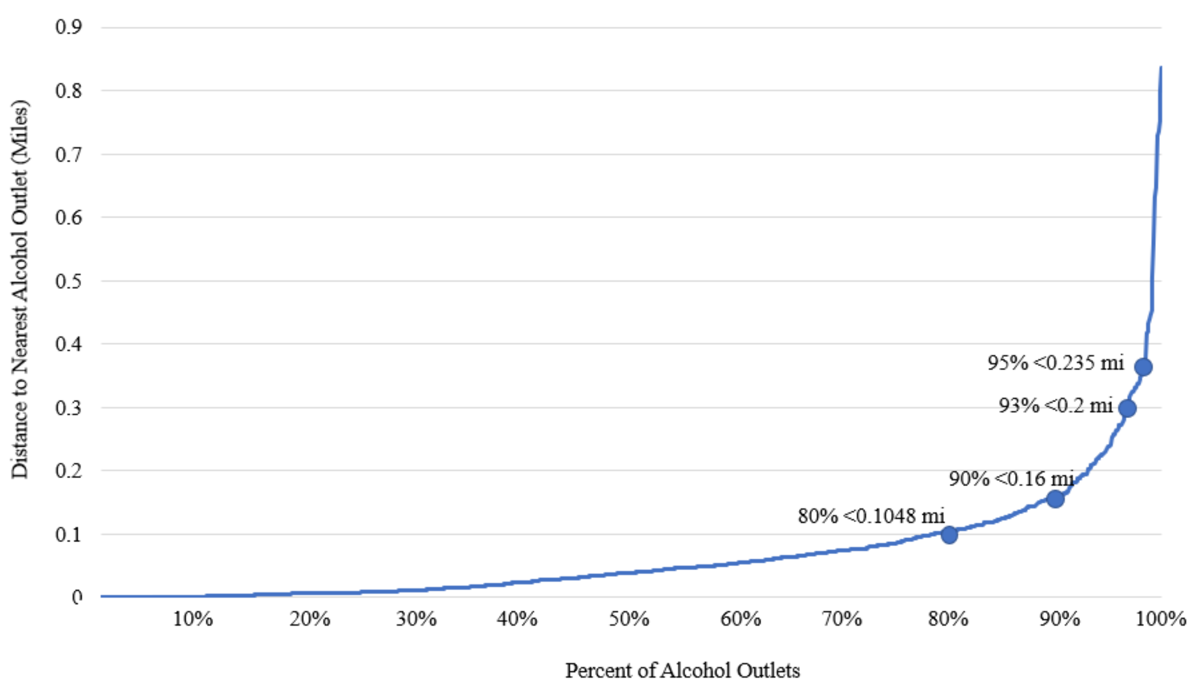
Figure A-7. Distribution of Violent Crime Exposure Variables



High Alcohol Outlet Density Cluster Indicator

Alcohol outlet density was measured by defining high-density clusters. Seventy-nine percent of alcohol outlets were located less than 0.1 miles from the nearest alcohol outlet, and 88% were located with 0.15 miles. Thus, the study compared a 0.1-mile and a 0.15-mile buffer to identify high-density areas. The analysis created a buffer around each alcohol outlet and merged overlapping buffers. Sets of overlapping buffers made up of 50 or more alcohol outlets were defined as high-density clusters. Ultimately, the 0.1-mile buffer provided a more precise fit, identifying 102 CBGs (15.6%) as high-density areas. The 0.15-mile buffer identified nearly half of the city (302 CBGs, 46%) as high-density areas, and there was a cluster just below the 50-outlet threshold (comprised of 40 outlets). Thus, the analysis proceeded with the 0.1-mile buffer. A spatial join was used to identify the CBGs that contain high-density areas, and a binary variable was created to identify these high-density CBGs. In order to measure alcohol outlet density, areas with many outlets in close proximity to other outlets were identified. The analysis first determined that outlets were on average 0.02 miles (109 feet) from their nearest neighbor, which indicated the presence of clustering (Nearest neighbor ratio 0.15, Z=-56.38, p<0.001).

Figure A-8. Distance to Nearest Alcohol Outlet



As 80-90% of outlets had their nearest outlet between 0.1 and 0.15 miles away, the analysis compared using these two buffer sizes to identify high-density clusters. Clusters were defined as areas with intersecting buffers that contained 50 or more alcohol outlets. The 0.1-mile buffer identified three high-density areas comprised of 82, 92, and 559 outlets corresponding to 102 (15.6%) CBGs. The 0.15-mile buffer identified one high-density area comprised of 905 outlets, corresponding to 302 (46%) of CBGs. Ultimately, the 0.1-mile buffer was selected because it identified a more specific area of the city with dense alcohol access, and 50 outlets was a more natural break for defining high-density clusters.

Figure A-9. High-Density Alcohol Outlet Clusters Using a 0.1-Mile and a 0.15-Mile Buffer

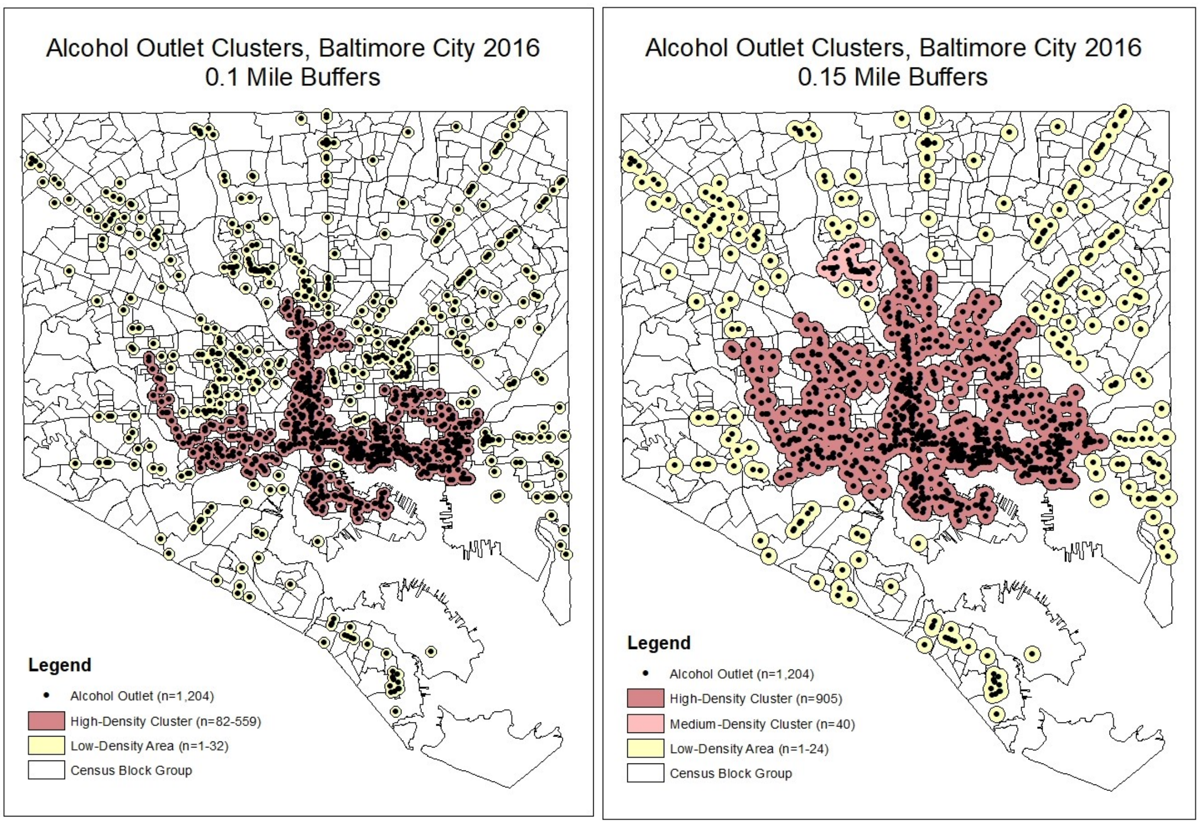


Figure A-10. Cluster Sizes from 0.1 Mile Buffers Around Alcohol Outlets

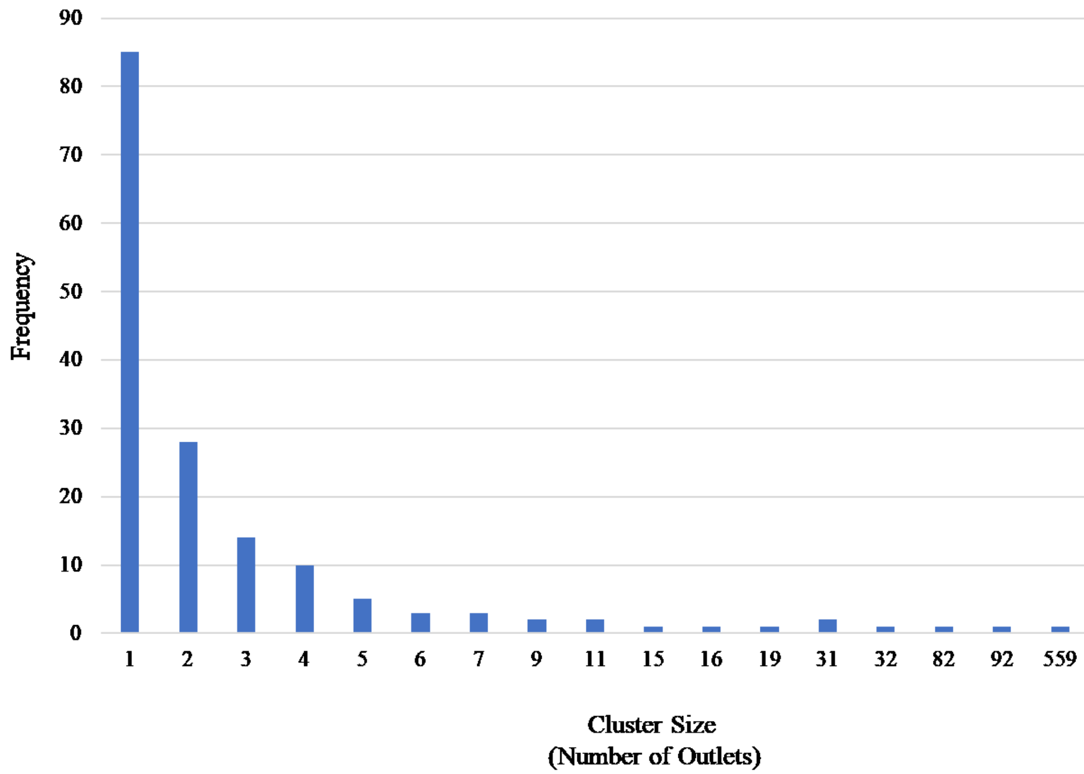
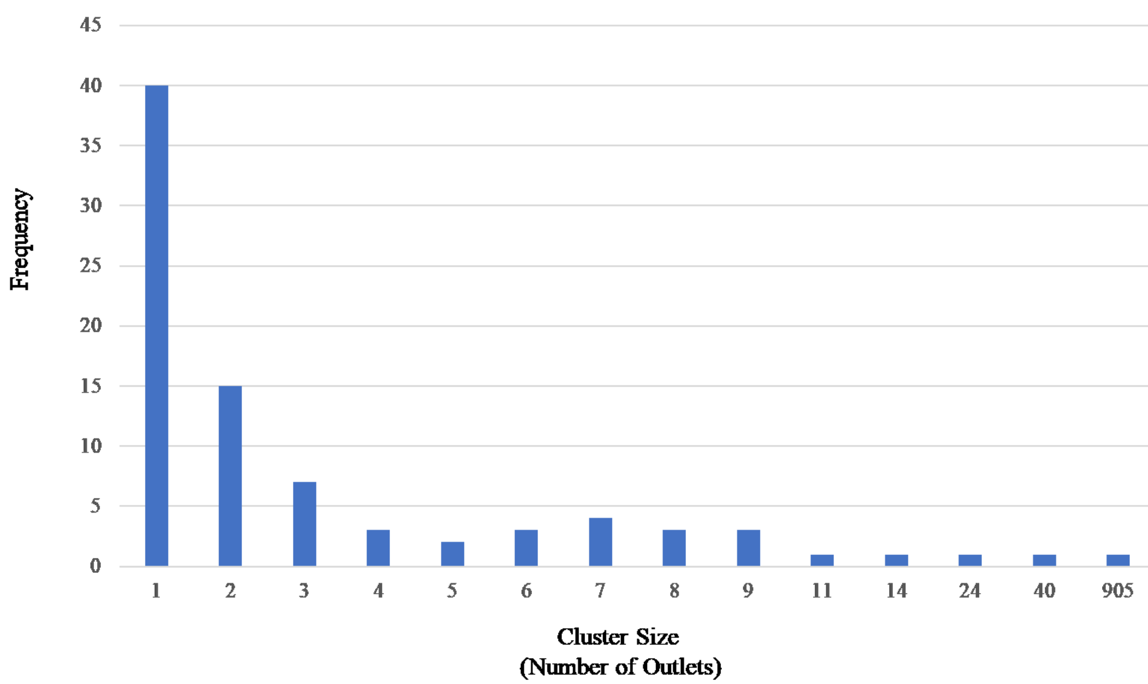


Figure A-11. Cluster Sizes from 0.15 Mile Buffers Around Alcohol Outlets



Variables for the regressions were selected using social disorganization theory and best subset selection (see Table A-2). The analysis considered including count of drug arrests, household size, median annual household income, percent owner-occupied homes, percent of the population who is African American, percent of the population aged 18-35 years old, percent of the population aged 16 or older in the labor force who are unemployed, population density, a social disadvantage index (includes percent of households living in poverty, percent female-headed households, percent of the population aged 25 or older with a college degree, and percent owner-occupied housing), and count of vacant houses. Count of drug arrests, percent aged 18 to 35 years, and population density were selected for all 32 models. Percent of the population who are African American (24 models, 75%), count of vacant homes (22 models, 69%), and median annual household income (21 models, 66%) were included in the majority of the models. The analysis did not include percent unemployed (11 models, 34%), household size (8 models, 25%), the social disadvantage index (8 models, 25%), or owner-occupied housing (7 models, 22%) because they did not explain enough variance to justify the cost in degrees of freedom. The final models included count of drug arrests, median annual household income, percent of the population who is African American, percent of the population aged 18-35 years old, population density, and count of vacant houses.

Table A-2. Best Subset Selection Results

Outcome	Predictor	Drug arrests	Household size	Median annual household income	Owner-occupied housing	Percent African American	Percent aged 18-35 years	Percent unemployment	Population density	Social disadvantage index	Vacant houses
Count of violent crime	Raw count with no denominator[a]	X		X			X		X	X	X
	Count weighted by population[b]	X		X			X		X	X	X
	Count weighted by area (square miles)[c]	X		X			X		X	X	X
	Count weighted by roadway miles[d]	X		X			X		X	X	X
	Proximity to nearest outlet[e]	X		X	X		X		X	X	X
	SAI to seven nearest outlets[f]	X		X	X		X		X	X	X
	SAI to all outlets in a 0.5-mile buffer[g]	X		X	X		X		X	X	X
	Mean distance to seven nearest outlets[h]	X		X	X		X		X	X	X
Proximity to Nearest Violent Crime	Raw count with no denominator	X				X	X	X	X		X
	Count weighted by population	X				X	X	X	X		X
	Count weighted by area (square miles)	X				X	X		X		X
	Count weighted by roadway miles	X				X	X	X	X		X
	Proximity to nearest outlet	X		X		X	X		X		
	SAI to seven nearest outlets	X		X		X	X		X		
	SAI to all outlets in a 0.5-mile buffer	X				X	X	X	X		
	Mean distance to seven nearest outlets	X		X		X	X		X		
SAI for seven nearest violent crimes	Raw count with no denominator	X	X	X		X	X	X	X		X
	Count weighted by population	X	X	X		X	X	X	X		X
	Count weighted by area (square miles)	X	X	X		X	X	X	X		X
	Count weighted by roadway miles	X	X	X		X	X	X	X		X
	Proximity to nearest outlet	X	X	X		X	X	X	X		
	SAI to seven nearest outlets	X	X	X		X	X	X	X		X
	SAI to all outlets in a 0.5-mile buffer	X	X			X	X	X	X		X
	Mean distance to seven nearest outlets	X	X	X		X	X		X		
	Raw count with no denominator	X				X	X		X		X

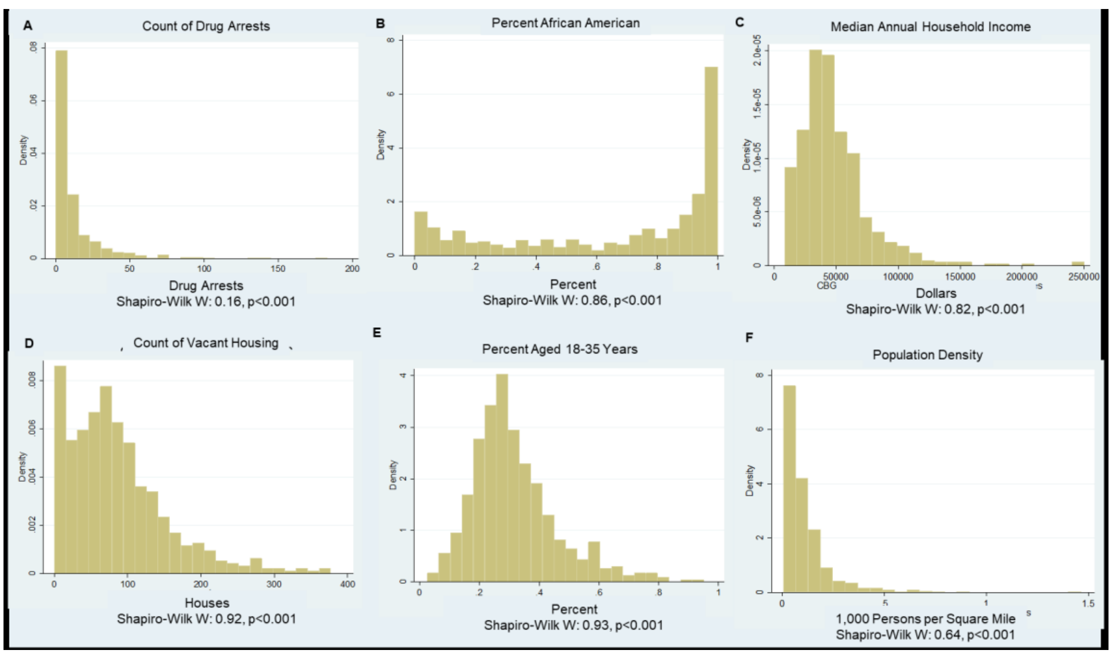
Outcome	Predictor	Drug arrests	Household size	Median annual household income	Owner-occupied housing	Percent African American	Percent aged 18-35 years	Percent unemployment	Population density	Social disadvantage index	Vacant houses
SAI for all violent crimes within a 0.25-mile buffer	Count weighted by population	X				X	X		X		X
	Count weighted by area (square miles)	X				X	X		X		X
	Count weighted by roadway miles	X				X	X		X		X
	Proximity to nearest outlet	X		X	X	X	X		X		
	SAI to seven nearest outlets	X		X	X	X	X		X		
	SAI to all outlets in a 0.5-mile buffer	X				X	X		X		
	Mean distance to seven nearest outlets	X		X	X	X	X		X		

[a]Calculated as the number of alcohol outlets in a census block group.
[b]Calculated as the number of alcohol outlets in a census block group divided by the population for that census block group.
[c]Calculated as the number of alcohol outlets in a census block group divided by the area (in square miles) for that census block group.
[d]Calculated as the number of alcohol outlets in a census block group divided by the total roadway miles in that census block group.
[e]Calculated as the network distance to the nearest alcohol outlet.
[f]Calculated as the inverse network distance from the census block group centroid to the seven closest alcohol outlets.
[g]Calculated as the inverse network distance from the census block group centroid to all alcohol outlets within a 0.5-mile buffer.
[h]Calculated as the average network distance from the census block group centroid to the closest seven alcohol outlets.

Demographic Covariates

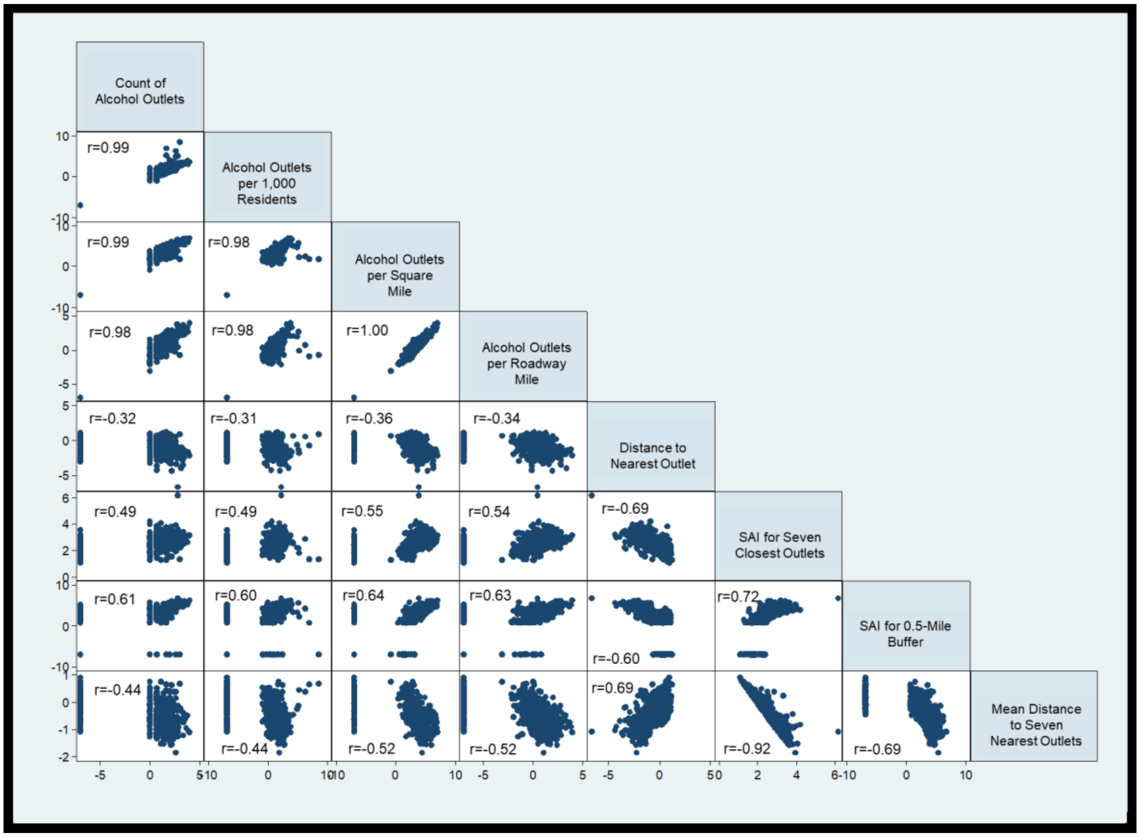
Figure A-12 shows histograms of the selected covariates. Count of drug arrests, median annual household income, count of vacant houses, percent of the population aged 18-35 years, and population density were all right skewed. Percent of the CBG who are African American had a bimodal distribution, which suggests trends of racial segregation (i.e., there were neighborhoods comprised mostly of African American residents as well as neighborhoods with no or almost no African Americans). The count of drug arrests was transformed using the natural logarithm, because it was the most skewed variable, and lowess smoothers showed a curvilinear relationship between the arithmetic count of drug arrests and the violent crime variables (data not shown). The log-transformed drug arrest count variable was roughly log-normal and had a linear relationship with the violent crime variables (data not shown).

Figure A-12. Histograms of Control Variables



The correlations between the alcohol outlet variables are shown in Figure A-13. The count-based variables correlate highly with one another (all $r \geq 0.98$). In fact, the count variable that uses an area-based denominator correlated perfectly with the count variable that uses a roadway miles-based denominator (r=1.0). On the other hand, the count-based variables have weak correlations with the proximity variable (r ranges from 0.32 to 0.36) and moderate correlations with the spatial access variables (r ranges from 0.44 to 0.64). The correlations between the count variables and the spatial access variables depended on whether the spatial access variables used a container; the correlations were highest in the container-based spatial access variable (i.e., the SAI for all outlets within a 0.5-mile radius) (r ranges from 0.61-0.64) and lower among the spatial access variables that do not use containers (r ranges from 0.49 to 0.55). The proximity and spatial access variables have a moderate correlation (r ranges from 0.60 to 0.69) with one another. Lastly, the spatial access variables have moderate to strong correlations (r ranges from 0.69 to 0.92). The container-based SAI with a 0.5-mile buffer had lower correlations with the spatial access variables that do not use a container; the correlation with the SAI for the seven nearest outlets was 0.72 and the correlation with the mean distance to the seven nearest outlets was 0.69. The two spatial access variables that did not use containers (i.e., the SAI for the seven nearest outlets and the mean distance to the seven nearest outlets) had a very strong correlation with one another (r=0.92). The trends in these correlations suggest that the count-based and spatial access variables measure separate constructs.

Figure A-13. Scatterplot Matrix of Alcohol Outlet Variables



Figures A-14 through A-17 show lowess smoothers for the log-transformed alcohol outlet access and violent crime exposure variables. Across all the series of figures, the count-based variables, particularly the count divided by population (B) and count divided by area (C), appear to have a curvilinear relationship with the measures of violent crime. This trend is most pronounced in Figure A-17, which shows the association between the alcohol outlet access variables and the log-transformed SAI of violent crimes within a 0.25-mile buffer. In addition, the other container-based variables, which include the count of alcohol outlets (A), count of outlets divided by roadway miles (D), and SAI for outlets within a 0.5-mile buffer (G). The associations of the other variables with the count-based measure of violent crime appear roughly linear.

Figure A-14. Lowess Smoothers for Alcohol Outlet Access Variables and the Natural Log of the Crime Rate

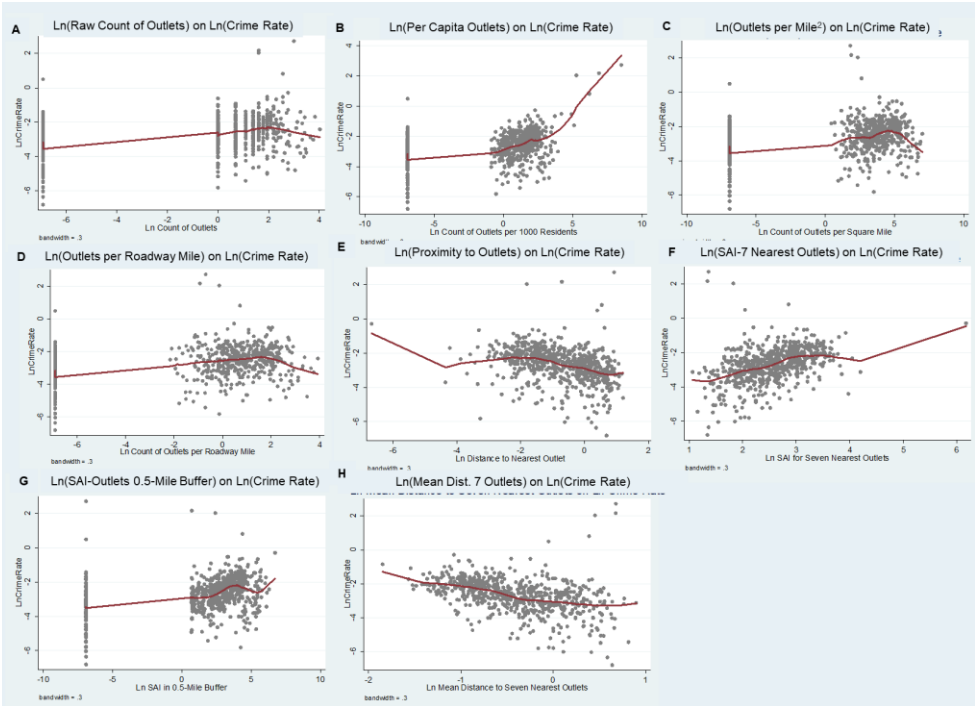


Figure A-15. Lowess Smoothers for Alcohol Outlet Variables and the Natural Log of the Proximity to the Nearest Violent Crime

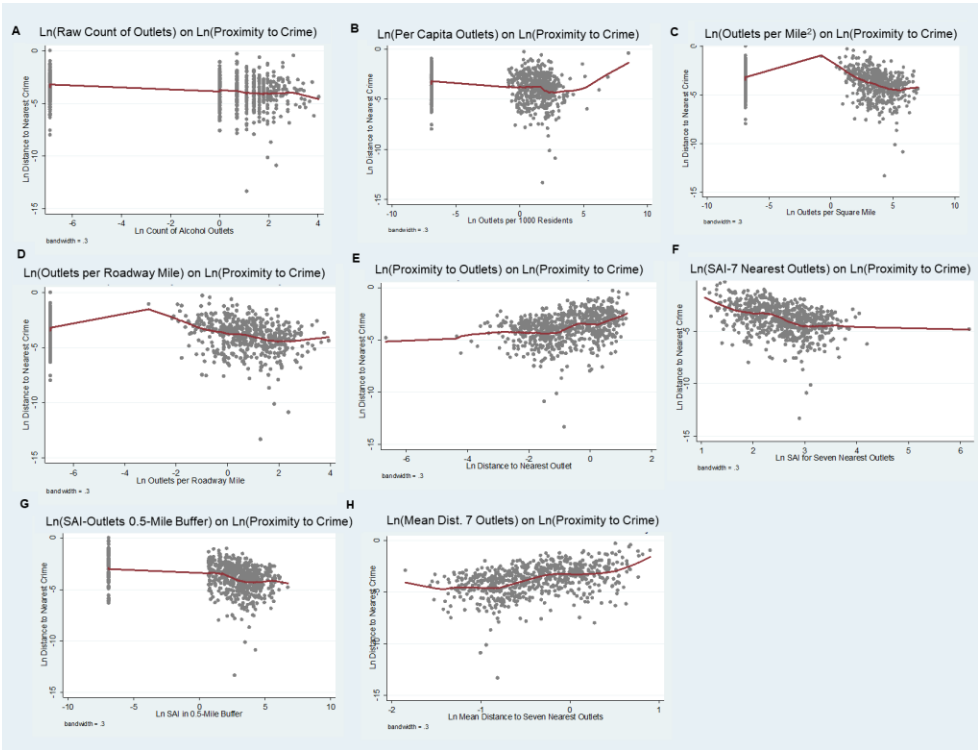


Figure A-16. Lowess Smoothers for Alcohol Outlet Access Variables and Spatial Access Violent Crime using Seven Nearest Crimes

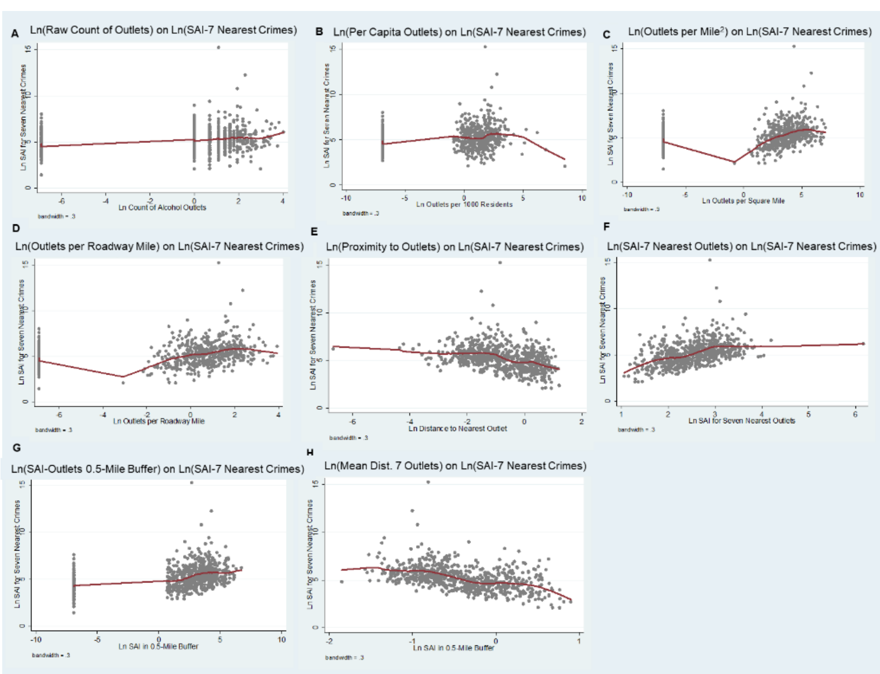
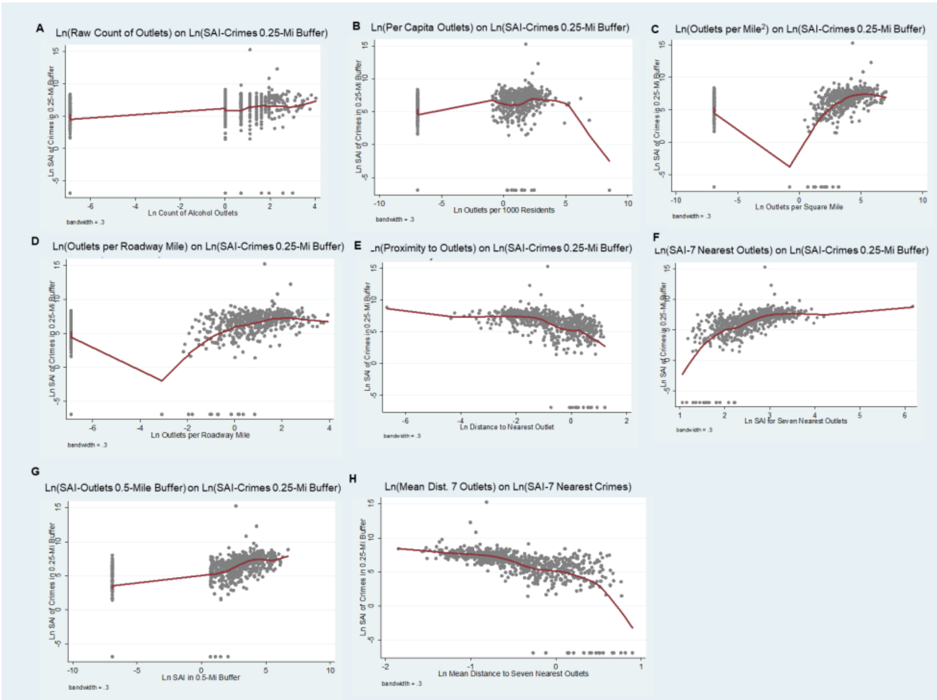


Figure A-17. Lowess Smoothers for Spatial Access Index using 0.25-Mile Buffer for Violent Crime



Analysis

Main Analyses

Table A-3 presents the results from the 32 models with an interaction term that allows the effect of alcohol outlet access to differ in low- and high-density areas. Of the 19 regressions with a significant high-density variable, only five had a positive interaction between the measure of alcohol outlet access and high-density clusters; this was the case in models 1 (*IRR*=0.95, p<0.05), 3 (*IRR*=0.96, p<0.05), 4 (*IRR*=0.95, p<0.05), 24 (β=0.87, p<0.05), and 32 (β=1.41, p<0.05).

Table A-3. Main Regression Analyses of Alcohol Outlet Access on Violent Crime Exposure with Interaction Term, Baltimore City 2016

	Count of Violent Crime		Proximity to Crime		SAI to 7 Nearest Crime		SAI to Crimes in 0.25-Mile Buffer	
	IRR	95% CI	β	95% CI	β	95% CI	β	95% CI
Raw count with no denominator[a]	1.04***	1.02, 1.05	-0.04*	-0.07, -0.01	0.04**	0.02, 0.07	0.08**	0.03, 0.12
Drug arrests	1.06***	1.05, 1.08	-0.02	-0.05, 0.01	0.02	>-0.01, 0.04	0.09***	0.05, 0.13
Percent African American	14.59**	2.14, 99.38	-9.38***	-13.47, -5.29	8.85***	5.44, 12.26	17.29***	11.36, 23.22
Vacant housing	1.17***	1.09, 1.26	-0.09	-0.25, 0.08	0.16*	0.02, 0.29	0.18	-0.06, 0.42
Median annual household income	0.91***	0.89, 0.93	0.03	-0.02, 0.07	-0.04	-0.07, <0.01	-0.03	-0.10, 0.03
Percent population aged 18-35	1.05	0.73, 1.50	-1.03*	-1.83, -0.23	1.09**	0.42, 1.76	1.95**	0.79, 3.11
Population density	1.47*	1.02, 2.12	2.87***	2.02, 3.71	-2.62***	-3.32, -1.91	-8.75***	-9.98, -7.53
High-density cluster	1.73***	1.50, 1.99	-0.29	-0.61, 0.03	0.32*	0.06, 0.59	1.06***	0.60, 1.52
Interaction (count*cluster)	0.96*	0.92, 0.99	-0.05	-0.14, 0.04	0.03	-0.05, 0.10	-0.02	-0.15, 0.12
Count weighted by population[a]	1.04***	1.03, 1.06	-0.04*	-0.07, -0.01	0.04**	0.01, 0.07	0.07**	0.02, 0.11
Drug arrests	1.06***	1.05, 1.08	-0.02	-0.05, 0.01	0.02	>-0.01, 0.04	0.09***	0.06, 0.13
Percent African American	18.74**	2.83, 124.14	-9.22***	-13.30, -5.15	8.69***	5.29, 12.09	16.95***	11.03, 22.86
Vacant housing	1.16***	1.08, 1.25	-0.09	-0.26, 0.07	0.16*	0.02, 0.30	0.19	-0.05, 0.43
Median annual household income	0.91***	0.89, 0.93	0.03	-0.02, 0.07	-0.03	-0.07, 0.01	-0.03	-0.10, 0.03
Percent population aged 18-35	1.04	0.73, 1.49	-1.05*	-1.85, -0.25	1.11**	0.44, 1.78	1.98**	0.82, 3.15
Population density	1.51*	1.05, 2.18	2.84***	1.99, 3.69	-2.59***	-3.30, -1.89	-8.72***	-9.95, -7.49
High-density cluster	1.73***	1.50, 1.99	-0.29	-0.61, 0.03	0.33*	0.06, 0.59	1.07***	0.60, 1.53
Interaction (count/pop*cluster)	0.97	0.93, 1.01	-0.05	-0.14, 0.04	0.02	-0.05, 0.10	-0.02	-0.15, 0.11
Count weighted by area[c]	1.03***	1.02, 1.04	-0.03**	-0.06, -0.01	0.04**	0.02, 0.06	0.06**	0.03, 0.10
Drug arrests	1.07***	1.05, 1.08	-0.02	-0.05, 0.01	0.02	>-0.01, 0.04	0.09***	0.05, 0.13
Percent African American	12.48**	1.86, 83.72	-9.20***	-13.25, -.15	8.69***	5.31, 12.07	16.98***	11.10, 22.85
Vacant housing	1.18***	1.09, 1.27	-0.09	-0.25, 0.08	0.16*	0.02, 0.29	0.18	-0.05, 0.42
Median annual household income	0.91***	0.89, 0.93	0.03	-0.02, 0.07	-0.03	-0.07, <0.01	-0.03	-0.09, 0.04
Percent population aged 18-35	1.03	0.72, 1.48	-1.01*	-1.82, -0.21	1.07**	0.40, 1.74	1.92**	0.76, 3.09
Population density	1.60*	1.10, 2.31	2.74***	1.88, 3.59	-2.48***	-3.19, -1.77	-8.54***	-9.78, -7.30
High-density cluster	1.90***	1.60, 2.25	-0.22	-0.59, 0.16	0.30	-0.01, 0.61	1.13***	0.60, 1.68
Interaction (count/area*cluster)	0.96*	0.93, 0.99	-0.03	-0.10, 0.04	0.01	-0.05, 4.99	-0.03	-0.13, 0.07
Count weighted by roadway miles[c]	1.04***	1.02, 1.05	-0.04*	-0.07, -0.01	0.05**	0.02, 0.07	0.08**	0.03, 0.13
Drug arrests	1.07***	1.05, 1.08	-0.02	-0.0, 0.01	0.02	>-0.01, 0.04	0.09***	0.05, 0.13
Percent African American	11.65*	1.74, 78.22	-9.16***	-13.21, -5.11	8.65***	5.28, 12.03	16.88***	11.00, 22.75
Vacant housing	1.18***	1.09, 1.27	-0.09	-0.26, 0.07	0.16*	0.03, 0.30	0.19	-0.05, 0.43
Median annual household income	0.91***	0.89, 0.93	0.03	-0.02, 0.07	-0.04	-0.07, <0.01	-0.03	-0.10, 0.04

	Count of Violent Crime		Proximity to Crime		SAI to 7 Nearest Crime		SAI to Crimes in 0.25-Mile Buffer	
	IRR	95% CI	β	95% CI	β	95% CI	β	95% CI
Percent population aged 18-35	1.03	0.71, 1.48	-1.02*	-1.82, -0.21	1.07**	0.40, 1.74	1.92**	0.76, 3.09
Population density	1.59*	1.10, 2.30	2.73***	1.87, 3.58	-2.47***	-3.19, -1.76	-8.54***	-9.78, -7.30
High-density cluster	1.71***	1.48, 1.97	-0.31	-0.63, 0.01	0.34*	0.08, 0.60	1.06***	0.60, 1.52
Interaction (count/road*cluster)	0.95*	0.90, 0.99	-0.05	-0.14, 0.05	0.02	-0.06, 0.10	-0.03	-0.17, 0.11
Proximity to nearest outlet[d]	0.82***	0.76, 0.89	0.32***	0.17, 0.48	-0.33***	-0.46, -0.21	-0.77***	-0.99, -0.55
Drug arrests	1.06***	1.05, 1.08	-0.01	-0.04, 0.01	0.01	-0.01, 0.04	0.07***	0.04, 0.11
Percent African American	15.19**	2.34, 98.65	-9.45***	-13.45, -5.46	8.93***	5.62, 12.24	18.52***	12.87, 24.17
Vacant housing	1.13**	1.05, 1.22	-0.05	-0.21, 0.12	0.11	-0.02, 0.25	0.05	-0.19, 0.28
Median annual household income	0.91***	0.89, 0.92	0.03	-0.01, 0.07	-0.04*	-0.07, >-0.01	-0.04	-0.10, 0.03
Percent population aged 18-35	0.88	0.61, 1.27	-0.76	-1.57, 0.05	0.82*	0.14, 1.49	1.30*	0.15, 2.44
Population density	1.98**	1.34, 2.94	2.27***	1.38, 3.17	-2.01***	-2.75, -1.27	-7.30***	-8.56, -6.03
High-density cluster	1.34*	1.02, 1.75	-0.09	-0.78, 0.59	0.1	-0.45, 0.69	0.79	-0.17, 1.76
Interaction (proximity*cluster)	0.94	0.83, 1.07	0.02	-0.30, 0.33	-0.01	-0.27, 0.25	0.10	-0.35, 0.55
SAI to 7 nearest outlets[e]	1.61***	1.44, 1.79	-0.52***	-0.76, -0.29	0.51***	0.31, 0.70	1.18***	0.85, 1.52
Drug arrests	1.06***	1.05, 1.07	-0.02	-0.04, 0.01	0.02	-0.01, 0.04	0.08***	0.04, 0.12
Percent African American	4.73	0.83, 27.03	-7.71***	-11.63, -3.78	7.14***	3.88, 10.41	14.46***	8.89, 20.02
Vacant housing	1.08*	1.01, 1.17	-0.04	-0.20, 0.13	0.11	-0.03, 0.25	0.02	-0.21, 0.26
Median annual household income	0.91***	0.89, 0.92	0.03	-0.01, 0.08	-0.04*	-0.08, >-0.01	-0.04	-0.10, 0.03
Percent population aged 18-35	0.71	0.49, 1.02	-0.77	-1.59, 0.04	0.85*	0.18, 1.53	1.30*	0.15, 2.45
Population density	2.62***	1.77, 3.88	2.11***	1.19, 3.02	-1.89***	-2.65, -1.12	-7.00***	-8.30, -5.70
High-density cluster	1.68	0.86, 3.27	-1.47	-3.20, 0.25	1.54*	0.10, 2.97	3.07*	0.63, 5.52
Interaction (SAI*cluster)	0.96	0.77, 1.20	0.43	-0.15, 1.01	-0.44	-0.92, 0.04	-0.78	-1.60, 0.04
SAI to all outlets in 0.5-mile buffer[f]	1.05***	1.03, 1.07	-0.06**	-0.09, -0.03	0.06***	0.03, 0.09	0.17***	0.12, 0.21
Drug arrests	1.06***	1.05, 1.07	-0.01	-0.04, 0.01	0.02	-0.01, 0.04	0.07**	0.03, 0.11
Percent African American	17.35**	2.63, 114.38	-9.69***	-13.76, -5.62	9.12***	5.73, 12.51	19.55***	13.82, 25.29
Vacant housing	1.14**	1.06, 1.23	-0.07	-0.23, 0.10	0.14	<0.01, 0.27	0.09	-0.15, 0.32
Median annual household income	0.91***	0.89, 0.93	0.03	-0.02, 0.07	-0.03	-0.07, <0.01	-0.02	-0.08, 0.04
Percent population aged 18-35	0.88	0.61, 1.28	-0.81	-1.63, <0.01	0.88*	0.20, 1.56	1.37*	0.22, 2.52
Population density	2.36***	1.58, 3.51	2.27***	1.36, 3.18	-2.03***	-2.79, -1.27	-7.04***	-8.33, -5.75
High-density cluster	1.29	0.72, 2.30	0.66	-0.82, 2.15	-0.68	-1.91, 0.56	-0.35	-2.44, 1.74
Interaction (SAI*cluster)	1.05	0.93, 1.19	-0.20	-0.52, 0.12	0.21	-0.06, 0.47	0.26	-0.19, 0.71
Mean distance to 7 nearest outlets[g]	0.65***	0.59, 0.71	0.47***	0.26, 0.68	-0.47***	-0.65, -0.30	-1.22***	-1.51, -0.92
Drug arrests	1.06***	1.05, 1.07	-0.01	-0.04, 0.01	0.01	-0.01, 0.04	0.07***	0.03, 0.11

	Count of Violent Crime		Proximity to Crime		SAI to 7 Nearest Crime		SAI to Crimes in 0.25-Mile Buffer	
	IRR	95% CI	β	95% CI	β	95% CI	β	95% CI
Percent African American	67.13***	10.51, 428.80	-10.83***	-14.97, -6.69	10.32***	6.89, 13.75	22.42***	16.63, 28.21
Vacant housing	1.07	0.99, 1.15	-0.02	-0.19, 0.14	0.09	-0.05, 0.23	-0.04	-0.28, 0.19
Median annual household income	0.91***	0.89, 0.93	0.03	-0.01, 0.08	-0.04*	-0.08, >-0.01	-0.04	-0.10, 0.03
Percent population aged 18-35	0.80	0.56, 1.15	-0.81*	-1.62, >-0.01	0.87*	0.21, 1.55	1.27*	0.14, 2.40
Population density	2.93***	1.96, 4.34	2.14***	1.23, 3.05	-1.89***	-2.64, -1.13	-6.80***	-8.08, -5.53
High-density cluster	1.13	0.81, 1.58	-0.44	-1.24, 0.36	0.49	-0.17, 1.16	0.86	-0.26, 1.98
Interaction (mean*cluster)	0.81	0.56, 1.17	-0.46	-1.35, 0.44	0.50	-0.24, 1.24	0.58	-0.67, 1.83

[a]Calculated as the number of alcohol outlets in a census block group.
[b]Calculated as the number of alcohol outlets in a census block group divided by the population for that census block group.
[c]Calculated as the number of alcohol outlets in a census block group divided by the area (in square miles) for that census block group.
[d]Calculated as the number of alcohol outlets in a census block group divided by the total roadway miles in that census block group.
[e]Calculated as the network distance to the nearest alcohol outlet.
[f]Calculated as the inverse network distance from the census block group centroid to the seven closest alcohol outlets.
[g]Calculated as the inverse network distance from the census block group centroid to all alcohol outlets within a 0.5-mile buffer.
[h]Calculated as the average network distance from the census block group centroid to the closest seven alcohol outlets.

Spatial Analyses

Moran's Index (Moran's I) was calculated on the measures of violent crime and regression standardized residuals using a first order Queen adjacency matrix requiring at least two adjacent sides to determine spatial dependence. A Monte Carlo estimation process was used for the distance-based and spatial access measurements. The violent crime variables all contained positive spatial autocorrelation (*Moran's I* ranged from 0.23 to 0.32, all $p<0.001$), indicating that observations were not independent (see Table A-4). Among the independent variables, proximity to the nearest crime (*Moran's I* 0.84, $p<0.001$) and the average distance to the seven nearest crimes (*Moran's I* 0.82, $p<0.001$) contained the greatest amount of spatial autocorrelation. The initial regressions accounted for more than 50% of the spatial dependence (count of violent crime *Moran's I* 0.12-0.15, $p<0.001$; proximity to violent crime *Moran's I* 0.05-0.06, $p<0.05$; SAI for seven nearest crimes *Moran's I* 0.05-0.07, $p<0.05$; SAI for crimes in 0.25-mile buffer *Moran's I* -0.01-0.01, $p>0.05$). While the *Moran's I* for models 1-24 are still statistically significant, a *Moran's I* of 0.05-0.15 is small. In addition, the negative binomial regression accounts for overdispersion. Lastly, the effects in the main regression models are highly significant (largest p value was $p=0.005$), so it is unlikely that adjusting for the remaining spatial dependence would change the inference. In combination, these circumstances mean the unadjusted models should be approximately accurate. Still, running spatial lag models and adding lag terms for the alcohol outlet access variables and/or covariates did not account for any additional spatial dependence (see Tables A-6 and A-7).

Table A-4. Moran's Index for Regression Models

Model	Count of Violent Crime		Proximity to Nearest Violent Crime		SAI to 7 Nearest Violent Crimes		SAI for Violent Crimes in 0.25-Mi Buffer	
	Morans' I	P Value	Morans' I	P Value	Morans' I	P Value	Morans' I	P Value
Before regression	0.32	<0.001	0.23	<0.001	0.30	<0.001	0.32	<0.001
Raw count with no denominator[a]	0.12	<0.001	0.05	0.02	0.06	0.01	-0.01	0.59
Count weighted by population[b]	0.12	<0.001	0.05	0.02	0.06	<0.01	-0.01	0.56
Count weighted by area[c]	0.12	<0.001	0.05	0.02	0.06	0.01	-0.01	0.60
Count weighted by roadway miles[d]	0.12	<0.001	0.05	0.01	0.06	0.01	-0.01	0.61
Proximity to nearest outlet[e]	0.14	<0.001	0.05	0.04	0.05	0.01	-0.01	0.60
SAI to seven nearest outlets[f]	0.15	<0.001	0.06	0.01	0.07	<0.01	0.01	0.31
SAI to all outlets in a 0.5-mile buffer[g]	0.12	<0.001	0.05	0.01	0.07	0.01	0.01	0.37
Mean distance to seven nearest outlets[h]	0.14	<0.001	0.06	<0.01	0.07	<0.001	>-0.01	0.46

SAI spatial accessibility index; Moran's I Moran's Index

[a]Calculated as the number of alcohol outlets in a census block group.

[b]Calculated as the number of alcohol outlets in a census block group divided by the population for that census block group.

[c]Calculated as the number of alcohol outlets in a census block group divided by the area (in square miles) for that census block group.

[d]Calculated as the number of alcohol outlets in a census block group divided by the total roadway miles in that census block group.

[e]Calculated as the network distance to the nearest alcohol outlet.

[f]Calculated as the inverse network distance from the census block group centroid to the seven closest alcohol outlets.

[g]Calculated as the inverse network distance from the census block group centroid to all alcohol outlets within a 0.5-mile buffer.

[h]Calculated as the average network distance from the census block group centroid to the closest seven alcohol outlets.

Table A-5. Moran's Index for Alcohol Outlet Access Variables

Variable	Moran's I	P Value
Before regression[a]	0.69	<0.001
Raw count with no denominator[b]	0.01	0.04
Count weighted by population[c]	0.60	<0.001
Count weighted by area[d]	0.52	<0.001
Count weighted by roadway miles[e]	0.84	<0.001
Proximity to nearest outlet[f]	0.14	<0.001
SAI to seven nearest outlets[g]	0.68	<0.001
SAI to all outlets in a 0.5-mile buffer[h]	0.82	<0.001

SAI spatial accessibility index; Moran's I Moran's Index
[a]Calculated as the number of alcohol outlets in a census block group.
[b]Calculated as the number of alcohol outlets in a census block group divided by the population for that census block group.
[c]Calculated as the number of alcohol outlets in a census block group divided by the area (in square miles) for that census block group.
[d]Calculated as the number of alcohol outlets in a census block group divided by the total roadway miles in that census block group.
[e]Calculated as the network distance to the nearest alcohol outlet.
[f]Calculated as the inverse network distance from the census block group centroid to the seven closest alcohol outlets.
[g]Calculated as the inverse network distance from the census block group centroid to all alcohol outlets within a 0.5-mile buffer.
[h]Calculated as the average network distance from the census block group centroid to the closest seven alcohol outlets.

Table A-6. Moran's I for Regression Models with Lag Term for Alcohol Outlet Access Variable

Model	Count of Violent Crime		Proximity to Nearest Violent Crime		SAI to 7 Nearest Violent Crimes		SAI for Violent Crimes in 0.25-Mile Buffer	
	Morans' I	P Value	Morans' I	P Value	Morans' I	P Value	Morans' I	P Value
Before regression	0.12	<0.001	0.05	0.02	0.06	0.01	-0.01	0.65
Raw count with no denominator[a]	0.12	<0.001	0.05	0.02	0.06	0.02	-0.01	0.62
Count weighted by population[b]	0.12	<0.001	0.05	0.02	0.05	0.01	-0.01	0.66
Count weighted by area[c]	0.12	<0.001	.0.05	0.02	0.05	0.01	-0.01	0.65
Count weighted by roadway miles[d]	0.14	<0.001	0.05	0.02	0.06	0.01	-0.01	0.65
Proximity to nearest outlet[e]	0.15	<0.001	0.06	0.01	0.07	<0.001	0.01	0.25
SAI to seven nearest outlets[f]	0.12	<0.001	0.05	0.01	0.07	<0.01	0.01	0.36
SAI to all outlets in a 0.5-mile buffer[g]	0.14	<0.001	0.06	0.01	0.07	<0.001	>-0.01	0.48

SAI spatial accessibility index; Moran's I Moran's Index
[a]Calculated as the number of alcohol outlets in a census block group.
[b]Calculated as the number of alcohol outlets in a census block group divided by the population for that census block group.
[c]Calculated as the number of alcohol outlets in a census block group divided by the area (in square miles) for that census block group.
[d]Calculated as the number of alcohol outlets in a census block group divided by the total roadway miles in that census block group.
[e]Calculated as the network distance to the nearest alcohol outlet.
[f]Calculated as the inverse network distance from the census block group centroid to the seven closest alcohol outlets.
[g]Calculated as the inverse network distance from the census block group centroid to all alcohol outlets within a 0.5-mile buffer.

Table A-7. Moran's I for Regression Models with Lag Terms for Covariates

Model	Count of Violent Crime		Proximity to Nearest Violent Crime		SAI to 7 Nearest Violent Crimes	
	Morans' I	P Value	Morans' I	P Value	Morans' I	P Value
Lagged Variable: Drug count						
Raw count with no denominator[a]	0.13	<0.001	0.05	0.01	0.06	0.01
Count weighted by population[b]	0.13	<0.001	0.05	0.02	0.06	0.01
Count weighted by area[c]	0.13	<0.001	0.05	0.02	0.06	0.01
Count weighted by roadway miles[d]	0.13	<0.001	0.05	0.03	0.06	0.01
Proximity to nearest outlet[e]	0.14	<0.001	0.04	0.04	0.05	0.03
SAI to seven nearest outlets[f]	0.14	<0.001	0.06	0.01	0.07	0.01
SAI to all outlets in a 0.5-mile buffer[g]	0.12	<0.001	0.05	0.02	0.06	0.01
Mean distance to 7 nearest outlets[h]	0.13	<0.001	0.05	0.01	0.06	0.01
Lagged Variable: Percent of Population African American						
Raw count with no denominator	0.13	<0.001	0.05	0.01	0.06	0.01
Count weighted by population	0.13	<0.001	0.05	0.01	0.06	<0.01
Count weighted by area	0.13	<0.001	0.05	0.01	0.06	0.01
Count weighted by roadway miles	0.13	<0.001	0.05	0.01	0.06	<0.01
Proximity to nearest outlet	0.14	<0.001	0.05	0.02	0.05	0.01
SAI to seven nearest outlets	0.15	<0.001	0.06	<0.01	0.07	<0.01
SAI to all outlets in a 0.5-mile buffer	0.12	<0.001	0.06	0.01	0.07	<0.01
Mean distance to 7 nearest outlets	0.14	<0.001	0.06	<0.01	0.07	<0.01
Lagged Variable: Count of Vacant Housing						
Raw count with no denominator	0.13	<0.001	0.06	0.01	0.06	0.01
Count weighted by population	0.13	<0.001	0.06	0.01	0.07	<0.01
Count weighted by area	0.13	<0.001	0.05	0.02	0.06	<0.01
Count weighted by roadway miles	0.13	<0.001	0.05	0.01	0.06	<0.01
Proximity to nearest outlet	0.14	<0.001	0.05	0.02	0.06	0.01
SAI to seven nearest outlets	0.15	<0.001	0.06	0.01	0.07	<0.01
SAI to all outlets in a 0.5-mile buffer	0.12	<0.001	0.06	0.02	0.07	0.01
Mean distance to 7 nearest outlets	0.14	<0.001	0.06	0.01	0.07	<0.001
Lagged Variable: Median Annual Household Income						
Raw count with no denominator	0.13	<0.001	0.05	0.01	0.06	0.01
Count weighted by population	0.13	<0.001	0.05	0.01	0.06	0.01
Count weighted by area	0.13	<0.001	0.05	0.01	0.06	0.01
Count weighted by roadway miles	0.13	<0.001	0.05	0.01	0.06	0.01
Proximity to nearest outlet	0.14	<0.001	0.05	0.03	0.05	0.01
SAI to seven nearest outlets	0.15	<0.001	0.06	<0.01	0.07	<0.001
SAI to all outlets in a 0.5-mile buffer	0.12	<0.001	0.05	0.01	0.06	0.01
Mean distance to 7 nearest outlets	0.14	<0.001	0.06	0.01	0.07	<0.01
Lagged Variable: Percent of Population Aged 18-35 Years						
Raw count with no denominator	0.11	<0.001	0.05	0.01	0.06	<0.01
Count weighted by population	0.11	<0.001	0.05	0.01	0.06	0.01
Count weighted by area	0.10	<0.001	0.05	0.02	0.06	0.01
Count weighted by roadway miles	0.11	<0.001	0.05	0.02	0.06	0.01
Proximity to nearest outlet	0.12	<0.001	0.05	0.03	0.05	0.01
SAI to seven nearest outlets	0.13	<0.001	0.06	0.01	0.07	<0.001
SAI to all outlets in a 0.5-mile buffer	0.11	<0.001	0.05	0.02	0.07	0.01
Mean distance to 7 nearest outlets	0.12	<0.001	0.06	0.01	0.07	<0.01
Lagged Variable: Population Density						

Model	Count of Violent Crime		Proximity to Nearest Violent Crime		SAI to 7 Nearest Violent Crimes	
	Morans' I	P Value	Morans' I	P Value	Morans' I	P Value
Raw count with no denominator	0.12	<0.001	0.06	0.01	0.07	0.01
Count weighted by population	0.12	<0.001	0.06	0.01	0.07	0.01
Count weighted by area	0.12	<0.001	0.06	0.02	0.06	0.01
Count weighted by roadway miles	0.12	<0.001	0.05	0.02	0.06	0.01
Proximity to nearest outlet	0.14	<0.001	0.05	0.02	0.06	0.01
SAI to seven nearest outlets	0.15	<0.001	0.06	0.01	0.07	<0.001
SAI to all outlets in a 0.5-mile buffer	0.12	<0.001	0.06	0.01	0.07	<0.01
Mean distance to 7 nearest outlets	0.13	<0.001	0.06	0.01	0.07	<0.001
Lagged Variable: High-Density Cluster Indicator						
Raw count with no denominator	0.13	<0.001	0.05	0.02	0.06	0.01
Count weighted by population	0.13	<0.001	0.05	0.02	0.06	0.01
Count weighted by area	0.13	<0.001	0.05	0.01	0.06	0.01
Count weighted by roadway miles	0.13	<0.001	0.05	0.03	0.06	0.01
Proximity to nearest outlet	0.14	<0.001	0.05	0.02	0.05	0.02
SAI to seven nearest outlets	0.15	<0.001	0.06	0.01	0.07	<0.01
SAI to all outlets in a 0.5-mile buffer	0.12	<0.001	0.05	0.01	0.06	0.01
Mean distance to 7 nearest outlets	0.14	<0.001	0.06	0.01	0.07	<0.01

SAI spatial accessibility index; Moran's I Moran's Index
[a]Calculated as the number of alcohol outlets in a census block group.
[b]Calculated as the number of alcohol outlets in a census block group divided by the population for that census block group.
[c]Calculated as the number of alcohol outlets in a census block group divided by the area (in square miles) for that census block group.
[d]Calculated as the number of alcohol outlets in a census block group divided by the total roadway miles in that census block group.
[e]Calculated as the network distance to the nearest alcohol outlet.
[f]Calculated as the inverse network distance from the census block group centroid to the seven closest alcohol outlets.
[g]Calculated as the inverse network distance from the census block group centroid to all alcohol outlets within a 0.5-mile buffer.
[h]Calculated as the average network distance from the census block group centroid to the closest seven alcohol outlets.

Sensitivity Analyses

Three sensitivity analyses were conducted: 1) Comparing census tracts (CTs) to CBGs, 2) Comparing different choice set sizes for the alcohol outlet access variables, and 3) Comparing different choice set sizes for the violent crime variables. Table A-8 presents the results from the first sensitivity analysis. The CT-level analysis has fewer and weaker statistically significant associations.

Table A-8. Sensitivity Analysis using Census Tracts as Unit of Analysis

Variables	Count of Violent Crime	Proximity to Violent Crime	Spatial Accessibility Index to Seven Nearest Violent Crimes
	IRR	β	β
Raw count with no denominator[a]	1.02*	0.01	0.03***
Drug arrests	1.14***	0.01	0.03
Percent African American	0.99	0.01	0.04*
Vacant housing	3.10***	1.24	0.73*
Median annual household income	0.86***	0.06	-0.07***
Percent population aged 18-35	1.19***	-0.06	0.11**
Population density	1.00	>-0.01	<0.01***
R^2	7.98	1.52	57.5
AIC	2,350.2	502.6	259.0
Proximity to nearest outlet[b]	0.82***	-0.07	-0.17***
Drug arrests	1.13***	0.01	0.04
Percent African American	1.00	0.01	0.03*
Vacant housing	2.49**	1.16	0.65
Median annual household income	0.87***	0.06	-0.06**
Percent population aged 18-35	1.17***	-0.06	0.10**
Population density	0.99*	>-0.01	<0.01***
R^2	8.69	1.82	57.1
AIC	2,319.7	499.6	260.2
SAI to seven nearest outlets[c]	1.43***	0.09	0.26***
Drug arrests	1.12***	0.01	0.03
Percent African American	1.02	0.02	0.04**
Vacant housing	1.76	1.10	0.42
Median annual household income	0.87***	0.06	-0.06**
Percent population aged 18-35	1.14***	-0.07	0.10**
Population density	0.99**	>-0.01	<0.01***
R^2	9.56	1.84	58.1
AIC	2,297.6	499.6	255.2
SAI to outlets in 0.5-mile buffer[d]	1.05	0.03	0.03*
Drug arrests	1.14	<0.01	0.04*
Percent African American	1.00	0.02	0.03
Vacant housing	2.47	1.09	0.76*
Median annual household income	0.88	0.08*	-0.06**
Percent population aged 18-35	1.15	-0.07	0.10**
Population density	0.99	>-0.01	<0.01***
R^2	8.81	2.4	55.7
AIC	2,329.1	500.9	267.3

SAI spatial accessibility index; IRR incident rate ratio; AIC Akaike's information criterion
*p<0.05, **p<0.01, ***p<0.001
[a]Calculated as the number of alcohol outlets in a census tract.
[b]Calculated as the minimum distance from the census tract centroid to the closest alcohol outlet.
[c]Calculated by summing the inverse distances from the census tract centroid to each of the seven closest alcohol outlets.
[d]Calculated by summing the inverse distances from the census tract centroid to each of the alcohol outlets within a 0.5-mile buffer.

Figure A-18 and Table A-9 summarize the results from the sensitivity analysis comparing different choice set sizes for the alcohol outlet SAI that used a choice set. Figure A-18 shows that areas of higher density (e.g., at the city center) have greater access in the graphs with larger choice set sizes, suggesting that smaller choice sets cannot detect dense clustering. In addition, there is greater small-scale variation (i.e., adjacent CBGs are more likely to have different SAIs) in maps with smaller choice set sizes. This is likely because larger choice set sizes smooth over larger areas. Across the regressions, the regression coefficient increased by approximately 0.1-0.2 per every five observations added to the spatial access calculation (see Table A-9). In addition, the AIC decreased by about one unit until the set included 25 outlets, where the AIC stabilized (see Figure A-19).

Figure A-18. Sensitivity Analysis for Alcohol Outlet SAI Choice Sets, Set Sizes 3-50

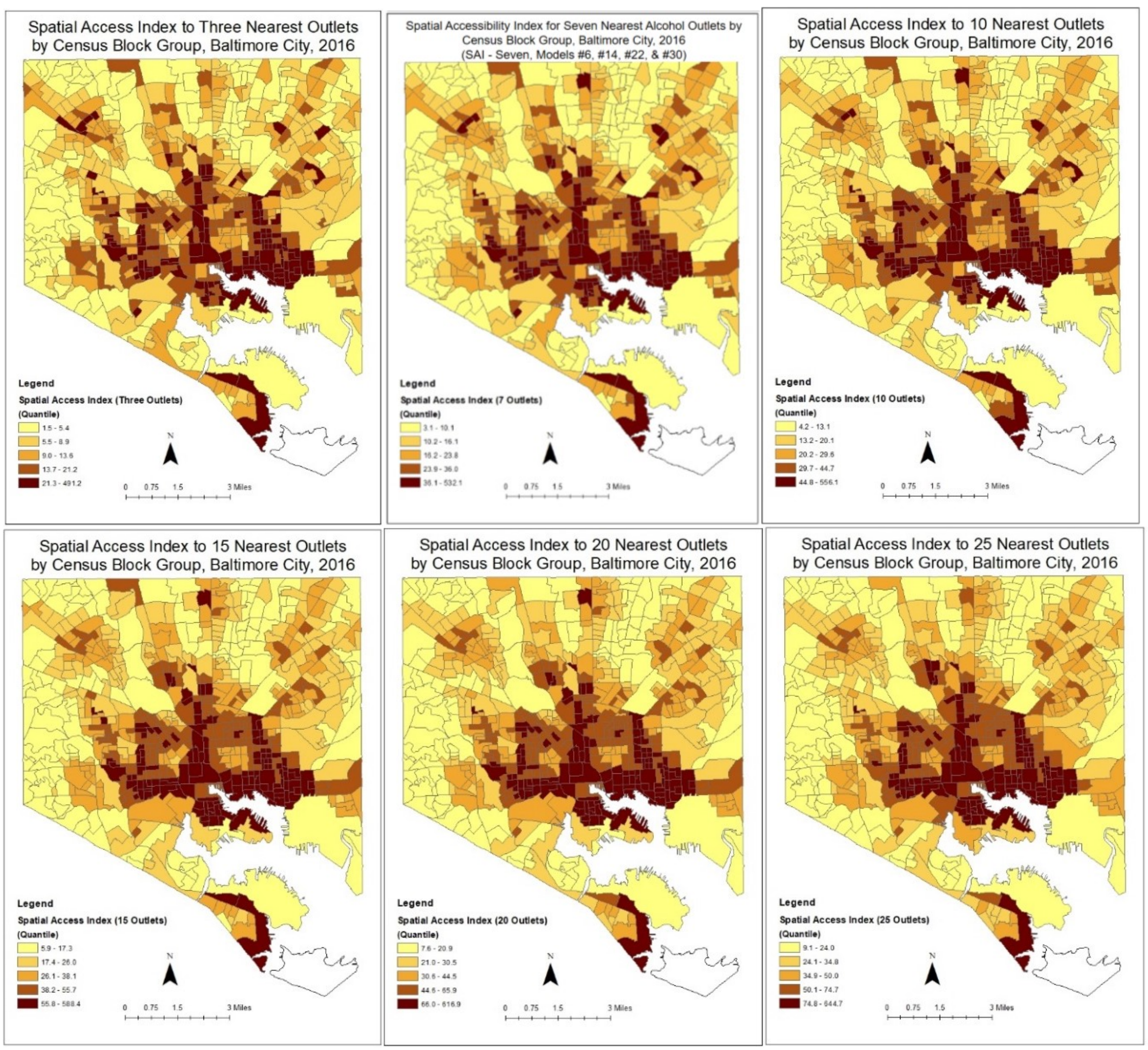


Figure A-18. Sensitivity Analysis for Alcohol Outlet SAI Choice Sets, Set Sizes 3-50 (Continued)

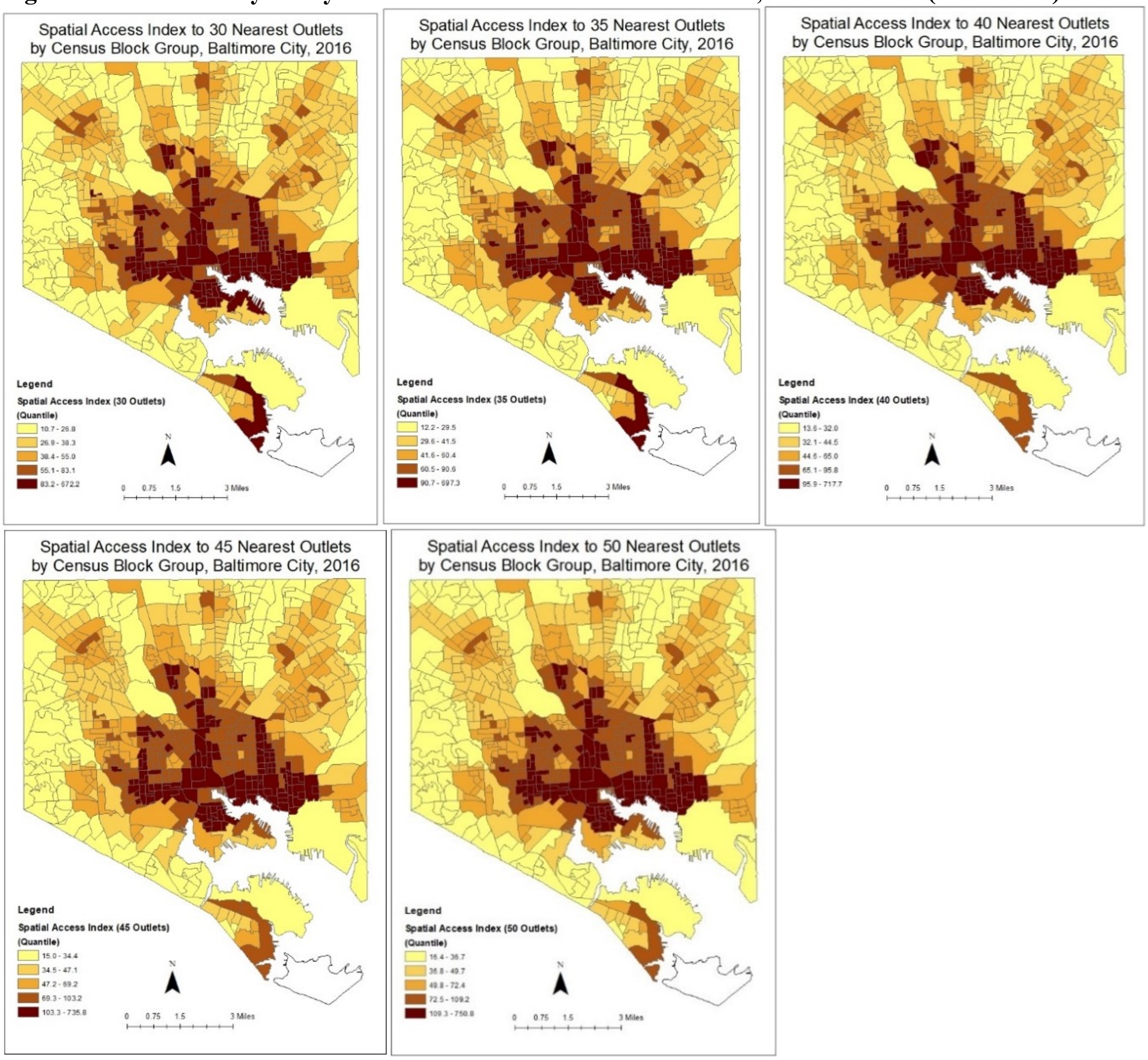
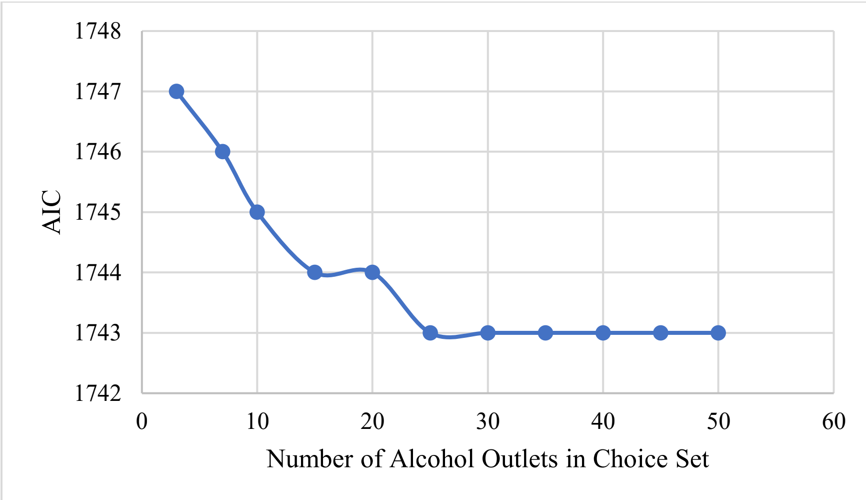


Figure A-19. AIC by Choice Set Size for Alcohol Outlet Spatial Accessibility Index



AIC Akaike's information criterion

Table A-9. Sensitivity Analysis for Spatial Access Index for Alcohol Outlets Choice Set Sizes, Set Sizes 3-50

Model	Three Outlets		Seven Outlets		10 Outlets		15 Outlets	
	β	**95% CI**	**β**	**95% CI**	**β**	**95% CI**	**β**	**95% CI**
SAI to nearest alcohol outlets[a]	0.41***	0.27, 0.55	0.45***	0.27, 0.63	0.49***	0.33, 0.66	0.53***	0.35, 0.70
Drug arrests	0.01	-0.01, 0.03	0.02	>-0.01, 0.04	0.01	-0.01, 0.04	0.01	-0.01, 0.04
Percent African American	9.67***	6.32, 13.02	7.09***	3.83, 10.36	10.08***	6.70, 13.46	10.11***	6.73, 13.48
Vacant housing	0.10	-0.04, 0.24	0.11	-0.03, 0.25	0.08	-0.06, 0.22	0.08	-0.06, 0.21
Median annual household income	-0.04*	-0.07, >-0.01	-0.04*	-0.07, >-0.01	-0.04*	-0.07, >-0.01	-0.04*	-0.07, >-0.01
Percent population aged 18-35	0.78*	0.44, 1.45	0.83*	0.15, 1.51	0.75*	0.07, 1.42	0.71*	0.04, 1.38
Population density	-1.89***	-2.64, -1.15	-1.99***	-2.74, -1.23	-1.84***	-2.59, -1.09	-1.82***	-2.57, -1.07
High-density cluster	0.10	-0.17, 0.38	0.23	-0.03, 0.50	0.06	-0.21, 0.34	0.04	-0.24, 0.31
AIC	1,747		1,746		1,745		1,744	
Model	**20 Outlets**		**25 Outlets**		**30 Outlets**		**35 Outlets**	
	β	**95% CI**	**β**	**95% CI**	**B**	**95% CI**	**β**	**95% CI**
SAI to nearest alcohol outlets	0.56***	0.37, 0.74	0.58***	0.39, 0.76	0.59***	0.40, 0.78	0.60***	0.41, 0.80
Drug arrests	0.01	-0.01, 0.04	0.01	-0.01, 0.04	0.01	-0.01, 0.04	0.02	-0.01, 0.04
Percent African American	10.12***	6.75, 13.49	10.12***	6.75, 13.48	10.09***	6.72, 13.45	10.05***	6.69, 13.42
Vacant housing	0.07	-0.07, 0.21	0.07	-0.07, 0.21	0.07	-0.07, 0.21	0.07	-0.07, 0.21
Median annual household income	-0.04*	-0.08, >-0.01	-0.04*	-0.07, >-0.01	-0.04*	-0.08, >-0.01	-0.04*	-0.08, >-0.01
Percent population aged 18-35	0.68*	0.01, 1.36	0.66	-0.01, 1.34	0.65	-0.03, 1.33	0.64	-0.04, 1.31
Population density	-1.81***	-2.55, -1.06	-1.80***	-2.55, -1.05	-1.8***	-2.55, -1.06	-1.81***	-2.56, -1.07
High-density cluster	0.02	-0.26, 0.30	>-0.01	-0.28, 0.28	-0.11	-0.29, 0.27	-0.02	-0.30, 0.26
AIC	1,744		1,743		1,743		1,743	

Table A-9. Sensitivity Analysis for Spatial Access Index for Alcohol Outlets Choice Set Sizes, Set Sizes 3-50 (Continued)

Model	40 Outlets		45 Outlets		50 Outlets	
	β	95% CI	B	β	95% CI	B
SAI to nearest alcohol outlets	0.61***	0.41, 0.81	0.62***	0.61***	0.41, 0.81	0.62***
Drug arrests	0.02	-0.01, 0.04	0.02	0.02	-0.01, 0.04	0.02
Percent African American	10.02***	6.66, 13.38	9.99***	10.02***	6.66, 13.38	9.99***
Vacant housing	0.07	-0.07, 0.21	0.07	0.07	-0.07, 0.21	0.07
Median annual household income	-0.04*	-0.08, >-0.01	-0.04*	-0.04*	-0.08, >-0.01	-0.04*
Percent population aged 18-35	0.63	-0.05, 1.30	0.61	0.63	-0.05, 1.30	0.61
Population density	-1.82***	-2.57, -1.08	-1.83**	-1.82***	-2.57, -1.08	-1.83**
High-density cluster	-0.03	-0.31, 0.26	-0.03	-0.03	-0.31, 0.26	-0.03
AIC	1,743		1,743	1,743		1,743

SAI spatial accessibility index; AIC Akaike's information criterion
*p<0.05, **p<0.01, ***p<0.001
[a]Calculated as the inverse network distance from the census block group centroid to the seven closest alcohol outlets.

Figure A-20 and Table A-10 show the results of the sensitivity analysis comparing different choice set sizes for the violent crime variables. The results are similar to the sensitivity analysis of choice set sizes for the alcohol outlet access variables; smaller choice set sizes contain greater variation across CBGs but have lower estimates for areas with dense violent crime. As shown in Table A-10, each additional 10 crimes added to the crime SAI reduced the AIC by 30 to 75 points, with larger reductions in the AIC for the initial additions to the choice set size.

Figure A-20. Choropleth Maps of Sensitivity Analysis for Violent Crime Spatial Accessibility Index Choice Set Size, Set Sizes 20-200

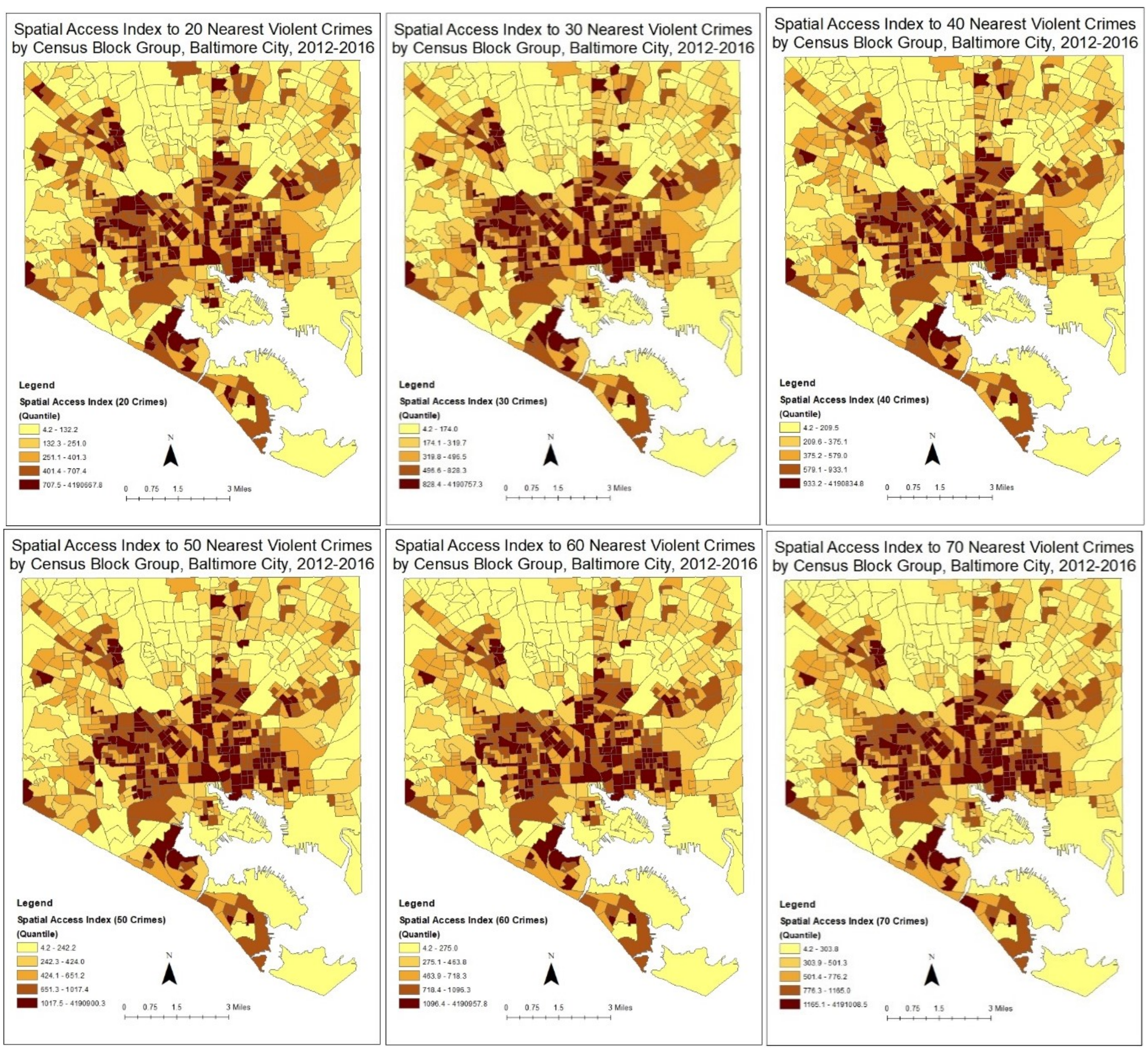


Figure A-20. Choropleth Maps of Sensitivity Analysis for Violent Crime Spatial Accessibility Index Choice Set Size, Set Sizes 20-200 (Continued)

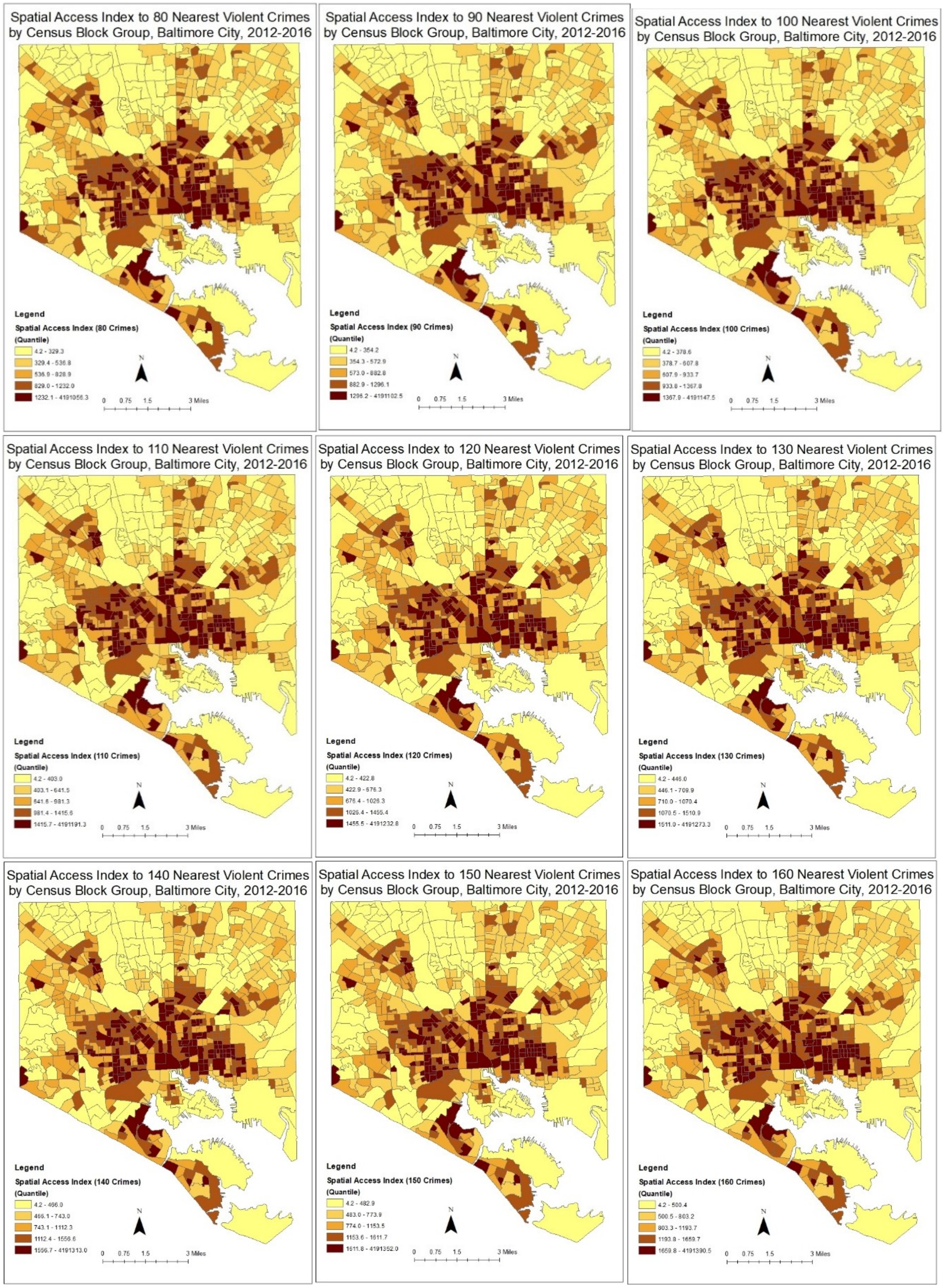
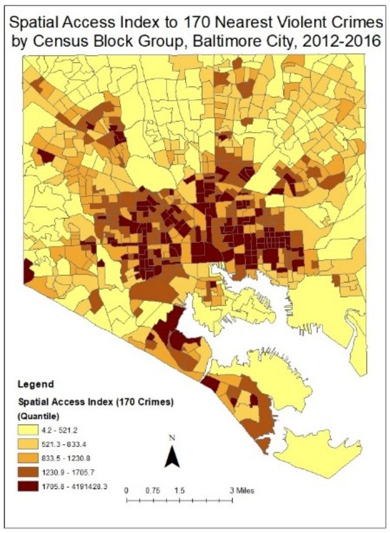
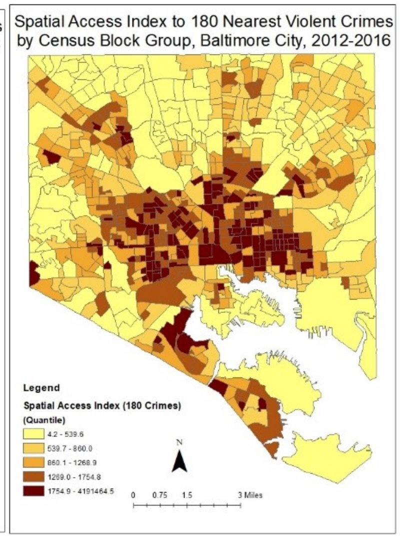
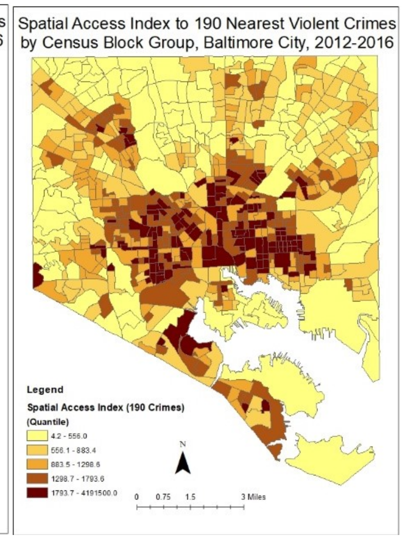


Figure A-20. Choropleth Maps of Sensitivity Analysis for Violent Crime Spatial Accessibility Index Choice Set Size, Set Sizes 20-200 (Continued)







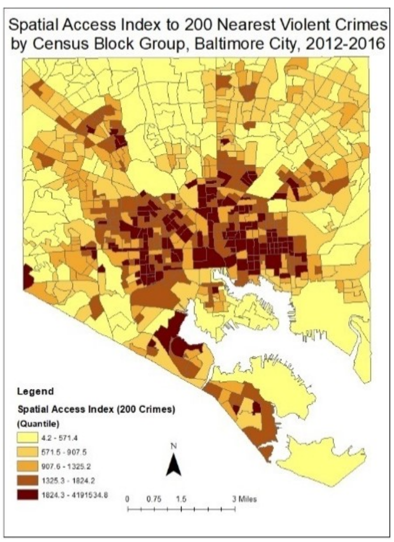


Table A-10. Sensitivity Analysis for Spatial Access Index for Violent Crime Choice Set Sizes, Set Sizes 10-200

	10 Crimes		20 Crimes		30 Crimes		40 Crimes	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
SAI to the seven nearest outlets[a]	0.45***	0.27, 0.63	0.46***	0.31, 0.60	0.46***	0.32, 0.59	0.46***	0.33, 0.58
Drug arrests	0.02	>-0.01, 0.04	0.02*	<0.01, 0.04	0.02*	<0.01, 0.04	0.02*	<0.01, 0.04
Percent African American	7.09***	3.83, 10.36	0.61***	0.35, 0.88	0.57***	0.32, 0.82	0.54***	0.30, 0.77
Vacant housing	0.11	-0.03, 0.25	<0.01	>-0.01, <0.01	<0.01	>-0.01, <0.01	<0.01	>-0.01, <0.01
Median annual household income	-0.04*	-0.07, >-0.01	-0.05**	-0.08, -0.02	-0.05**	-0.07, -0.02	-0.04**	-0.07, -0.02
Percent population aged 18-35	0.83	0.15, 1.51	0.23	-0.34, 0.81	0.22	-0.31, 0.75	0.22	-0.28, 0.72
Population density	-1.99***	-2.74, -1.23	0.03***	0.02, 0.04	0.03***	0.02, 0.04	0.03***	0.02, 0.04
High-density cluster	0.23	-0.03, 0.50	0.22	>-0.01, 0.44	0.22*	0.02, 0.43	0.22*	0.03, 0.42
AIC	1739.2		1520.9		1433.7		1371.2	
Moran's I	0.06*		0.06*		0.06*		0.06*	

	50 Crimes		60 Crimes		70 Crimes		80 Crimes	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
SAI to the seven nearest outlets	0.46***	0.33, 0.58	0.46***	0.34, 0.58	0.46***	0.34, 0.57	0.46***	0.34, 0.57
Drug arrests	0.02*	<0.01, 0.04	0.02**	0.01, 0.03	0.02**	0.01, 0.03	0.02**	0.01, 0.03
Percent African American	0.52***	0.29, 0.74	0.50***	0.28, 0.72	0.48***	0.27, 0.70	0.47***	0.26, 0.68
Vacant housing	<0.01	<0.01, <0.01	<0.01	<0.01, <0.01	<0.01	<0.01, <0.01	<0.01	<0.01, <0.01
Median annual household income	-0.04**	-0.07, 0.03	-0.04**	-0.07, -0.02	-0.04**	-0.07, -0.02	-0.04**	-0.07, -0.02
Percent population aged 18-35	0.21	-0.27, 0.70	0.21	-0.26, 0.68	0.20	-0.25, 0.67	0.20	-0.25, 0.64
Population density	0.03***	0.02, 0.03	0.03***	0.02, 0.03	0.03***	0.02, 0.03	0.02***	0.02, 0.03
High-density cluster	0.22*	0.04, 0.41	0.22*	0.04, 0.40	0.22*	0.05, 0.40	0.22*	0.05, 0.39
AIC	1322.9		1283.5		1250.5		1221.9	
Moran's I	0.06*		0.06*		0.06*		0.06*	

Table A-10. Sensitivity Analysis for Spatial Access Index for Violent Crime Choice Set Sizes, Set Sizes 10-200 (Continued)

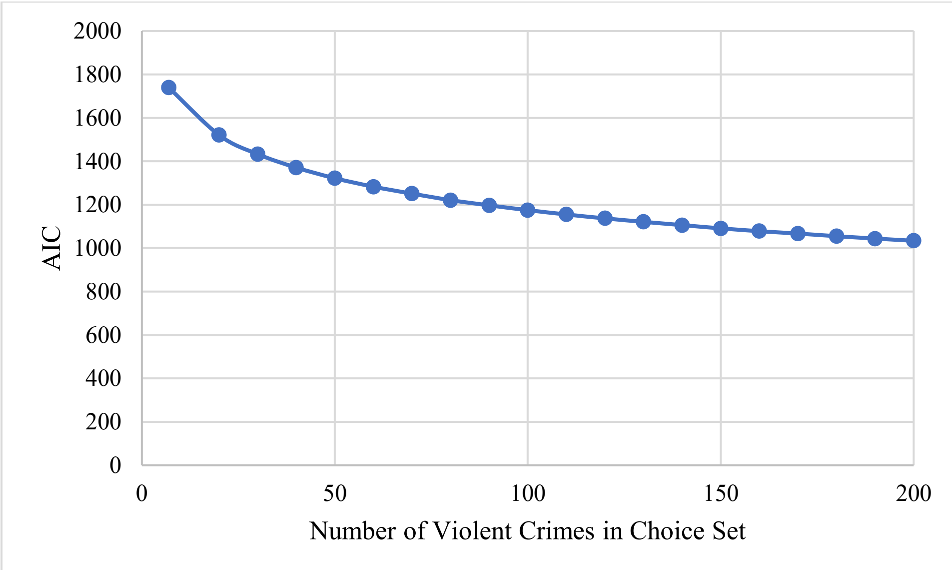
	90 Crimes		100 Crimes		110 Crimes		120 Crimes	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
SAI to the seven nearest outlets	0.45***	0.34, 0.57	0.45***	0.35, 0.56	0.45***	0.35, 0.56	0.45***	0.35, 0.56
Drug arrests	0.02**	0.01, 0.03	0.02**	0.01, 0.03	0.02**	0.01, 0.03	0.02**	0.01, 0.03
Percent African American	0.46***	0.26, 0.67	0.46***	0.25, 0.65	0.46***	0.25, 0.64	0.44***	0.25, 0.64
Vacant housing	<0.01*	<0.01, <0.01	<0.01*	-0.06, -0.02	<0.01*	-0.06, -0.02	<0.01*	-0.06, -0.02
Median annual household income	-0.04***	-0.06, -0.02	-0.04***	-0.24, 0.61	-0.04***	-0.24, 0.60	-0.04***	-0.24, 0.60
Percent population aged 18-35	0.19	-0.24, 0.63	0.19	0.02, 0.03	0.19	0.02, 0.03	0.19	0.02, 0.03
Population density	0.02***	0.02, 0.03	0.02***	0.06, 0.39	0.02***	0.07, 0.39	0.02***	0.07, 0.39
High-density cluster	0.23**	0.06, 0.39	0.23**	0.06, 0.39	0.23**	0.06, 0.39	0.23**	0.06, 0.39
AIC	1197.2		1175.3		1,155.5		1,137.4	
Moran's I	0.06*		0.06*		0.06*		0.06**	
	130 Crimes		140 Crimes		150 Crimes		160 Crimes	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
SAI to the seven nearest outlets	0.45***	0.35, 0.56	0.45***	0.35, 0.56	0.45***	0.35, 0.55	0.45***	0.35, 0.55
Drug arrests	0.02**	0.01, 0.03	0.02**	0.01, 0.03	0.02**	0.01, 0.03	0.02**	0.01, 0.03
Percent African American	0.44***	0.25, 0.63	0.43***	0.24, 0.62	0.43***	0.24, 0.61	0.42***	0.24, 0.61
Vacant housing	<0.01*	-0.06, -0.02	<0.01*	-0.06, -0.02	<0.01*	-0.06, -0.02	<0.01*	-0.06, -0.02
Median annual household income	-0.04***	-0.24, 0.58	-0.04***	-0.24, 0.57	-0.04***	-0.24, 0.56	-0.04***	-0.24, 0.55
Percent population aged 18-35	0.17	0.02, 0.03	0.16	0.02, 0.03	0.16	0.02, 0.03	0.15	0.02, 0.03
Population density	0.02***	0.07, 0.39	0.02***	0.07, 0.39	0.02***	0.07, 0.39	0.02***	0.08, 0.38
High-density cluster	0.23**	0.06, 0.39	0.23**	0.08, 0.39	0.23**	0.08, 0.39	0.23**	0.08, 0.38
AIC	1,120.9		1,105.8		1,091.8		1,078.9	
Moran's I	0.06**		0.06**		0.06*		0.06**	

Table A-10. Sensitivity Analysis for Spatial Access Index for Violent Crime Choice Set Sizes, Set Sizes 10-200 (Continued)

	170 Crimes		180 Crimes		190 Crimes		200 Crimes	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
SAI to the nearest outlets	0.45***	0.35, 0.55	0.45***	0.35, 0.55	0.45***	0.35, 0.55	0.45***	0.35, 0.55
Drug arrests	0.02**	0.01, 0.03	0.02**	0.01, 0.03	0.02**	0.01, 0.03	0.02**	0.01, 0.03
Percent African American	0.42***	0.23, 0.60	0.42***	0.23, 0.60	0.41***	0.23, 0.60	0.41***	0.23, 0.59
Vacant housing	<0.01*	-0.06, -0.02	<0.01*	-0.06, -0.02	<0.01*	-0.06, -0.02	0.08*	-0.06, -0.02
Median annual household income	-0.04***	-0.24, 0.54	-0.04***	-0.24, 0.54	-0.04***	-0.24, 0.54	-0.04***	-0.24, 0.54
Percent population aged 18-35	0.15	0.02, 0.03	0.15	0.02, 0.03	0.15	0.02, 0.03	0.14	0.02, 0.03
Population density	0.02***	0.08, 0.38	0.02***	0.08, 0.38	0.02***	0.08, 0.38	0.02***	0.08, 0.38
High-density cluster	0.23**	0.08, 0.38	0.23**	0.08, 0.38	0.23**	0.08, 0.38	0.23**	0.09, 0.38
AIC	1,066.9		1,055.5		1,044.9		1,034.8	
Moran's I	0.06**		0.07**		0.07**		0.07**	

SAI spatial accessibility index; AIC Akaike's information criterion; Moran's I Moran's Index
*p<0.05, **p<0.01, ***p<0.001
[a]Calculated as the inverse network distance from the census block group centroid to the seven closest alcohol outlets.

Figure A-21. AIC by Choice Set Size for Violent Crime Exposure Index



AIC Akaike's information criterion

Regression Diagnostics

Figures A-22 through A-25 present choropleth maps of the regression residuals from the 32 models. Figure A-22 shows the regression residuals for the eight models that use a count of violent crime. Of these eight models, model 6 (SAI with the seven nearest alcohol outlets) has a notably smaller range (442) than the counts (1,112-1,124), proximity (774) and other spatial access measures of alcohol outlet access (1,065-1,090). Downtown has a much larger residual than other CBGs. Downtown is an outlier because it has the largest number of violent crimes (n=1,215). Otherwise, the most extreme residuals appear to be located in CBGs with large counts of violent crime.

Figure A-23 shows the regression residuals for the eight models that use proximity to the nearest violent crime. These models all have substantially narrower ranges (12-13) than the count-based models in Figure A-22 (442-1,124). The proximity to the nearest violent crime appears to drive the residual size in these models. CBGs where the centroid is located farther away from the nearest violent crime tend to have larger residuals.

Figure A-24 shows the regression residuals for the eight models that use a SAI for the seven nearest violent crimes. These models have a similar range as the proximity models presented in Figure A-23. The largest residuals appear to be in CBGs with high access to violent crime, particularly those surrounded by areas of lower access to violent crime.

The regression residuals for the models with the SAI of violent crimes in a 0.25-mile buffer are presented in Figure A-25. Again, the range of the residuals for these models is narrower (19-21) than the count models (442-1,124) but it is wider than the proximity and SAI models using seven violent crimes (12-13). The most extreme small residuals in these models appear to be in CBGs with no alcohol outlets.

Figure A-22. Choropleth Maps of Regression Residuals with Count of Violent Crime

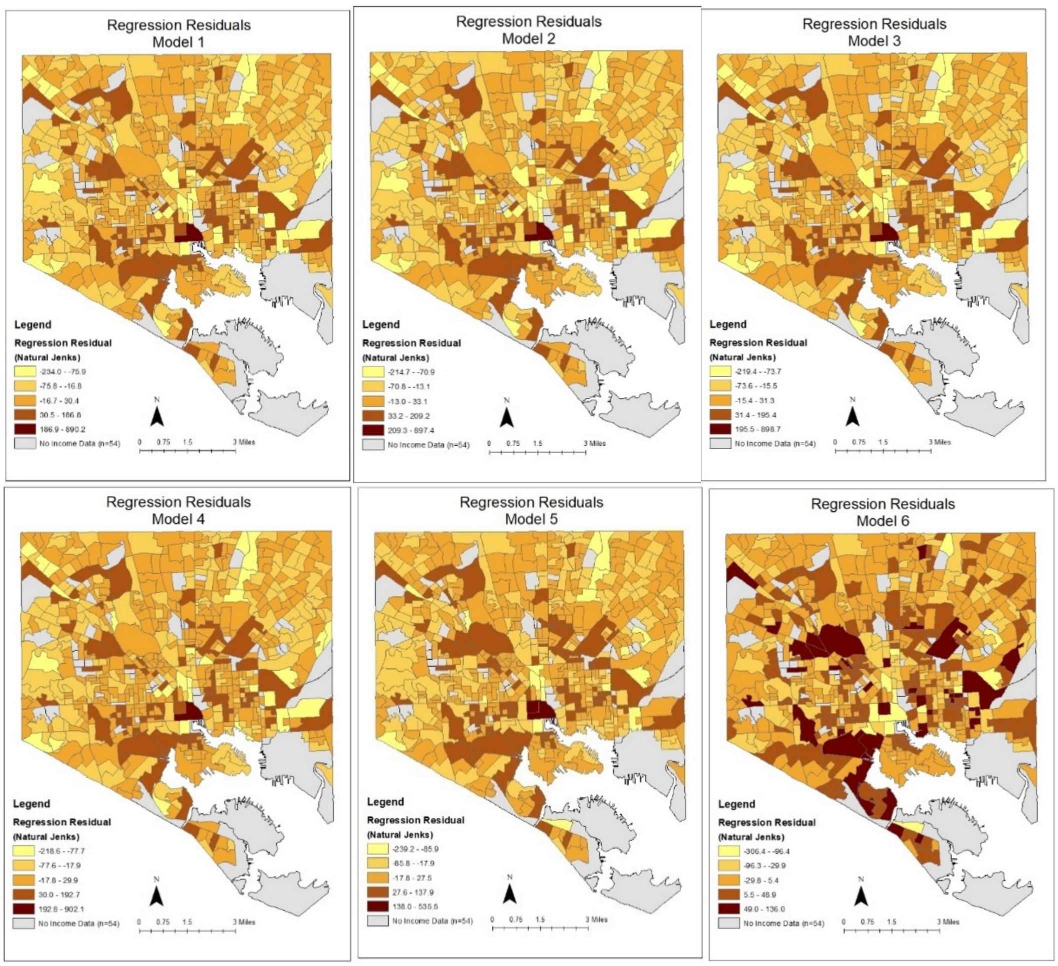
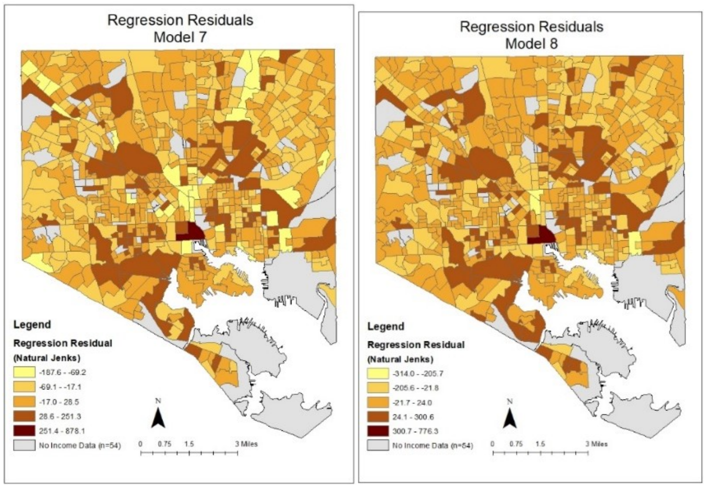
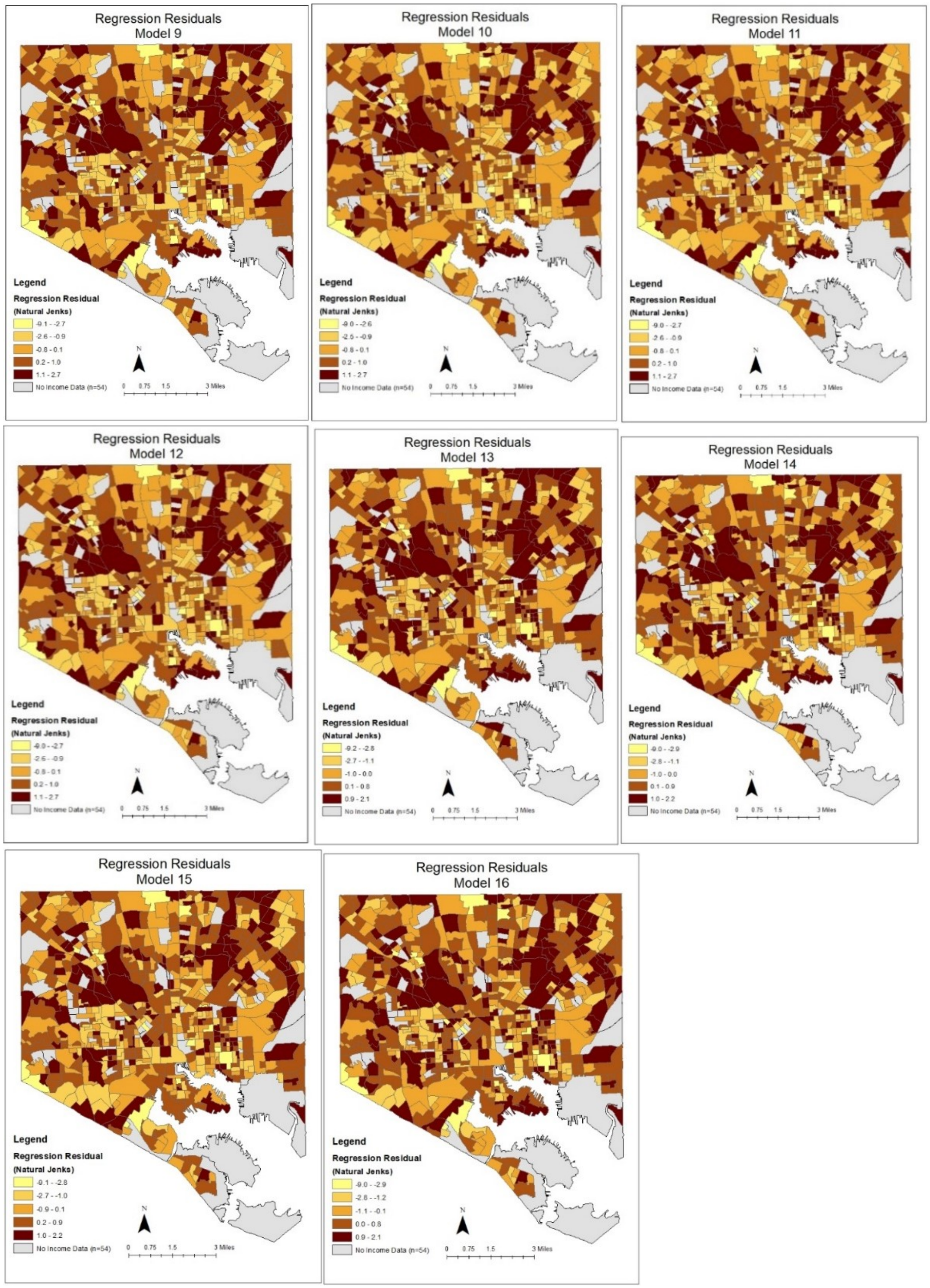


Figure A-22. Choropleth Maps of Regression Residuals with Count of Violent Crime (Continued)



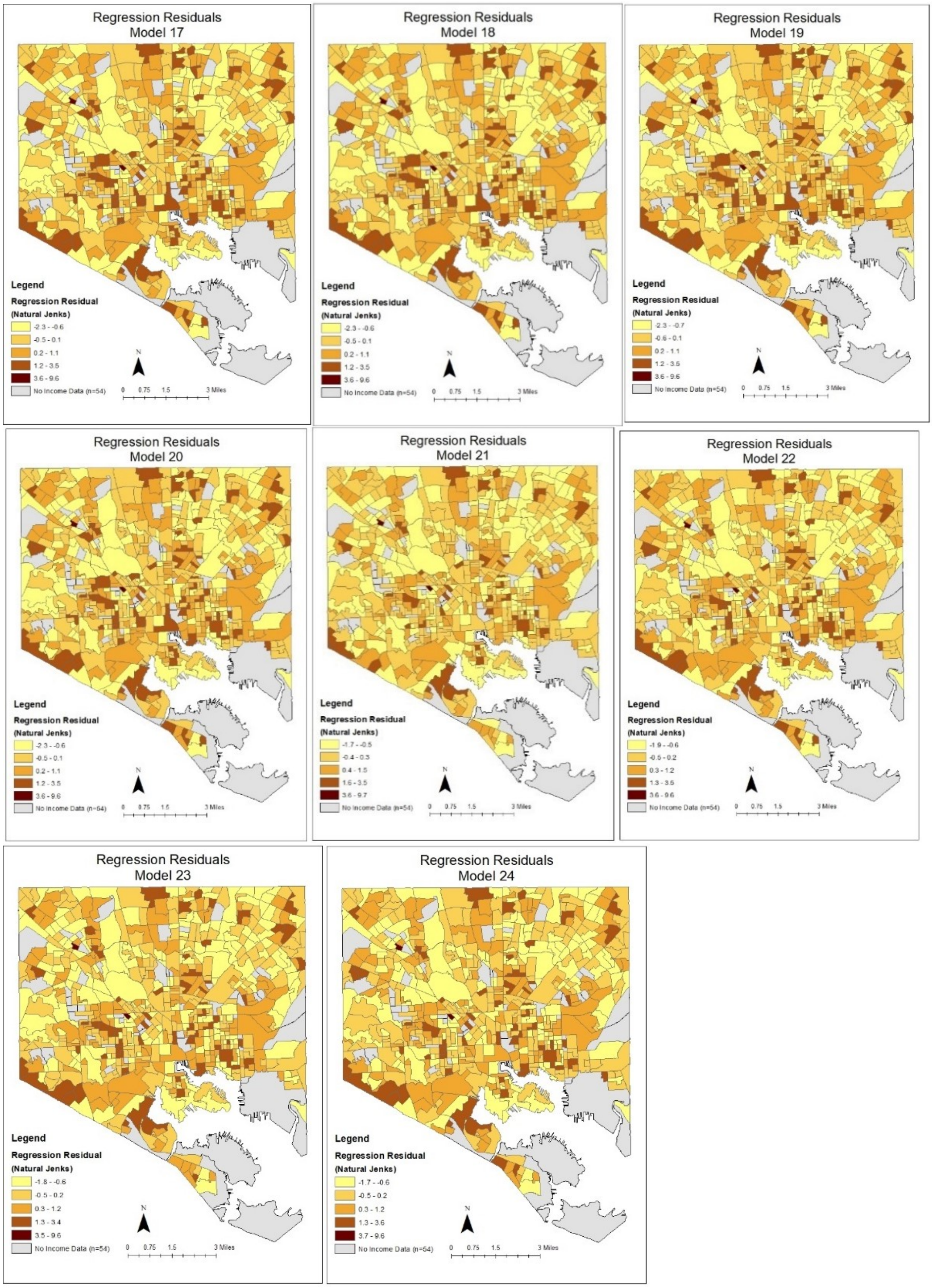
Model 1: Raw count of alcohol outlets in each CBG with no denominator
Model 2: Count of alcohol outlets in each CBG divided by total population
Model 3: Count of alcohol outlets in each CBG divided by area in square miles
Model 4: Count of alcohol outlets in each CBG divided by total roadway miles
Model 5: Proximity to the nearest alcohol outlet in network distance
Model 6: Spatial accessibility index using inverse network distance for seven nearest alcohol outlets
Model 7: Spatial accessibility index using inverse network distance for all alcohol outlets in a 0.5-mile buffer
Model 8: Mean network distance to seven nearest alcohol outlets

Figure A-23. Choropleth Maps of Regression Residuals with Proximity to Violent Crime



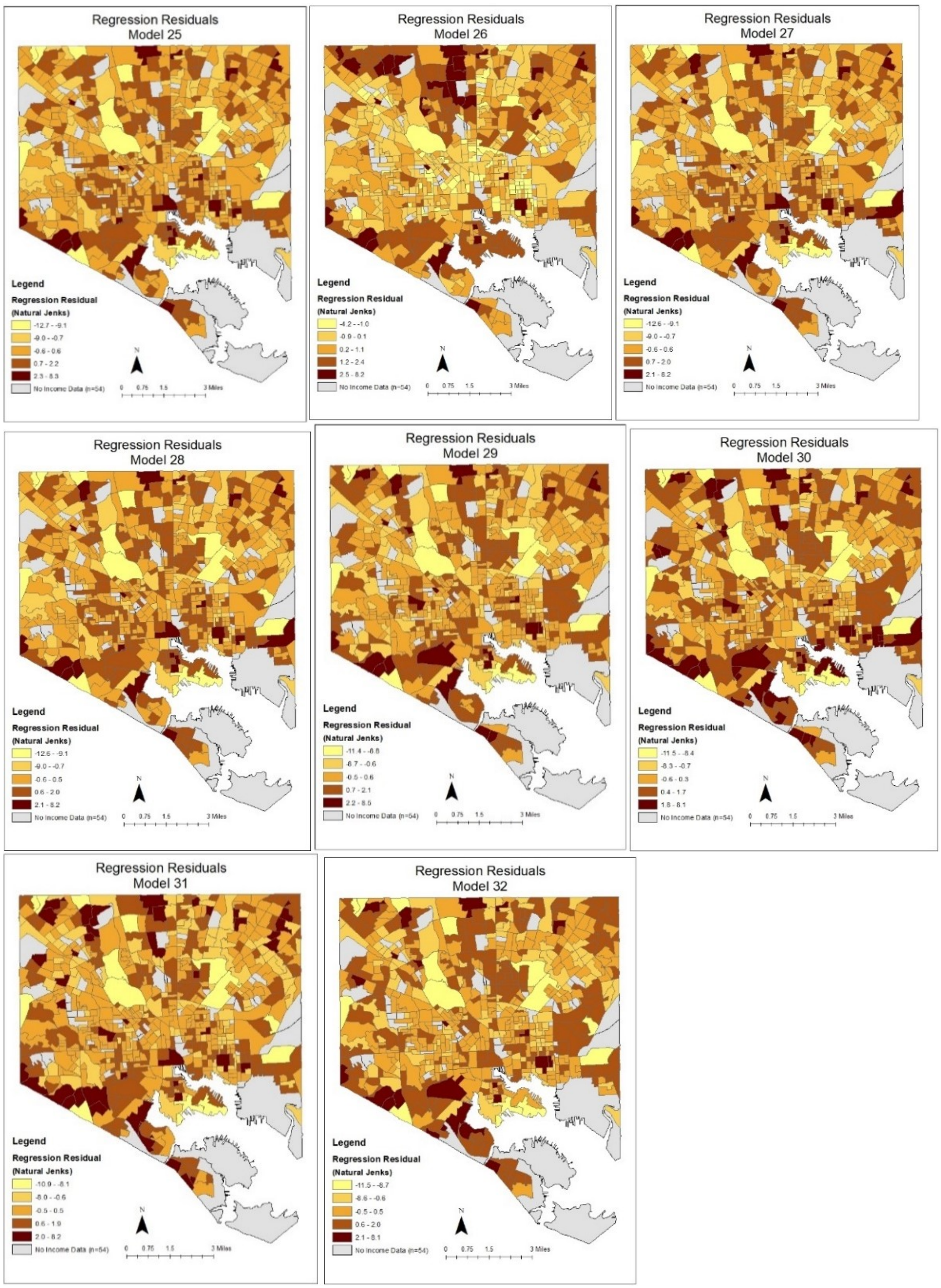
Model 9: Raw count of alcohol outlets in each CBG with no denominator
Model 10: Count of alcohol outlets in each CBG divided by total population
Model 11: Count of alcohol outlets in each CBG divided by area in square miles
Model 12: Count of alcohol outlets in each CBG divided by total roadway miles
Model 13: Proximity to the nearest alcohol outlet in network distance
Model 14: Spatial accessibility index using inverse network distance for seven nearest alcohol outlets
Model 15: Spatial accessibility index using inverse network distance for all alcohol outlets in a 0.5-mile buffer
Model 16: Mean network distance to seven nearest alcohol outlets

Figure A-24. Choropleth Maps of Regression Residuals for SAI to Seven Nearest Crimes



Model 17: Raw count of alcohol outlets in each CBG with no denominator
Model 18: Count of alcohol outlets in each CBG divided by total population
Model 19: Count of alcohol outlets in each CBG divided by area in square miles
Model 20: Count of alcohol outlets in each CBG divided by total roadway miles
Model 21: Proximity to the nearest alcohol outlet in network distance
Model 22: Spatial accessibility index using inverse network distance for seven nearest alcohol outlets
Model 23: Spatial accessibility index using inverse network distance for all alcohol outlets in a 0.5-mile buffer
Model 24: Mean network distance to seven nearest alcohol outlets

Figure A-25. Choropleth Maps of Regression Residuals for SAI of Crimes in 0.25-Mi Buffer



Model 25: Raw count of alcohol outlets in each CBG with no denominator
Model 26: Count of alcohol outlets in each CBG divided by total population
Model 27: Count of alcohol outlets in each CBG divided by area in square miles
Model 28: Count of alcohol outlets in each CBG divided by total roadway miles
Model 29: Proximity to the nearest alcohol outlet in network distance
Model 30: Spatial accessibility index using inverse network distance for seven nearest alcohol outlets
Model 31: Spatial accessibility index using inverse network distance for all alcohol outlets in a 0.5-mile buffer
Model 32: Mean network distance to seven nearest alcohol outlets

Methods for Chapter 4

Measures

Dichotomizing Demographics for Bivariate Analyses

The analysis dichotomized demographic variables to compare the distribution of alcohol outlets and violent crime. Exploratory data analysis was used to determine the best methods of dichotomizing the data based on the distribution, because dichotomizing continuous predictors can result in information loss, the potential to misunderstand associations, and artificial jumps in the outcome near the cut point [259]. To prevent such issues, sensitivity analyses were performed to attempt to minimize misclassification and other potential biases.

Race/Ethnicity. The analysis considered whether the population of a CBG is more than 50% African American. The sensitivity analysis compared three measures of dichotomizing percent African American:

1.) Composition: whether the CBG is 50% African American or more

2.) Mean: whether the CBG has a greater proportion of African American persons than the mean of 66.0%

3.) Median: whether the CBG has a greater proportion of African American persons than the median (82.6%)

Of the 204 CBGs with populations less than 50% African American, 161 (80%) have populations that are more than 50% White. Thus, categorizing CBGs as predominantly African American or White captures the distribution of 610 of the 653 CBGs (93%). All three methods reached the same inference: spatial access for on-premise and LBD-7 outlets is lower in CBGs with fewer African American residents. Thus, the analysis proceeded with the composition metric, because it was the easiest to explain.

Figure A-26. Histogram of Proportion of Population who are African American

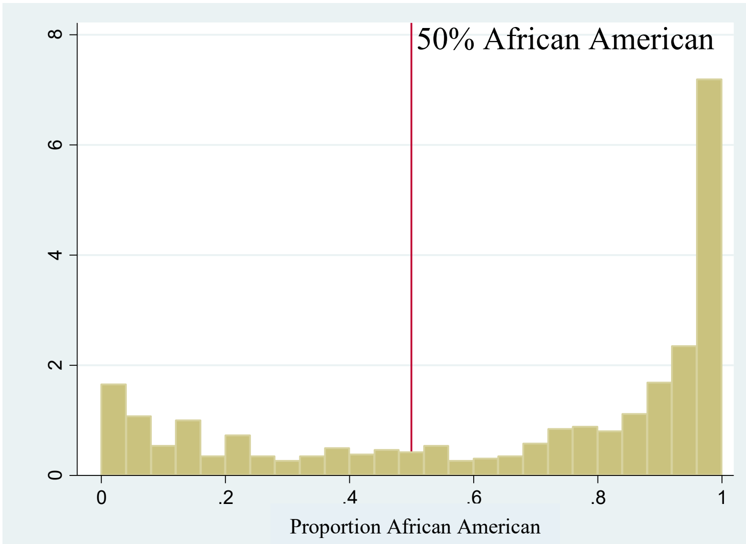


Table A-11. Sensitivity Analysis for Dichotomizing Percent African American

Demographic	Alcohol Outlet Type					
	On Premise		Off Premise		LBD-7	
	Mean	t	Mean	t	Mean	t
African American (Composition)						
50% or more (n=407)	13.28	6.66***	19.26	0.22	16.80	5.36***
Less than 50% (n=192)	29.38		18.70		28.01	
African American (Mean)						
66.0% or more (n=369)	12.79	7.01***	19.10	0.16	26.88	5.69***
Less than 66.0% (n=230)	27.49		18.74		16.35	
African American (Median)						
82.5% or more (n=300)	12.30	7.10***	19.44	-0.65	15.96	
Less than 82.5% (n=299)	24.59		18.30		24.84	5.66***

<u>Median Annual Household Income.</u> The analysis considered two cutpoints for dichotomizing median annual household income:

1.) \$25,000 and \$75,000: The \$25,000 and \$75,000 were chosen based on commonly-used survey cutpoints (e.g., Behavioral Risk Factor Surveillance Survey, National Survey of Drug Use and Health) and using the United States level for poverty level for a family of four (\$24,250). The benefit to this method is that it is intuitive to understand commonly-used thresholds.

2.) Quartiles: The lowest 25% of median annual household income values were less than \$30,000 and the highest 25% of these values were greater than \$59,375. The benefit to using quartiles to dichotomize this variable is ensuring there are more observations in the resulting low- and high-income groups.

The sensitivity analysis showed that the inference did not change based on whether low-income was defined as $25,000 or $30,000. However, the inference changed for on-premise and off-premise access, depending on how high-income was dichotomized. Using the $75,000 definition, on-premise access was higher, and off-premise access was lower in high income areas. Using the $59,375, the distribution of on- and off-premise outlets did not differ by income level. Thus, the $25,000 and $75,000 levels were used because their values had greater significance in the real world and to capture the differences in outlet distribution.

Figure A-27. Histograms of Median Annual Household Income

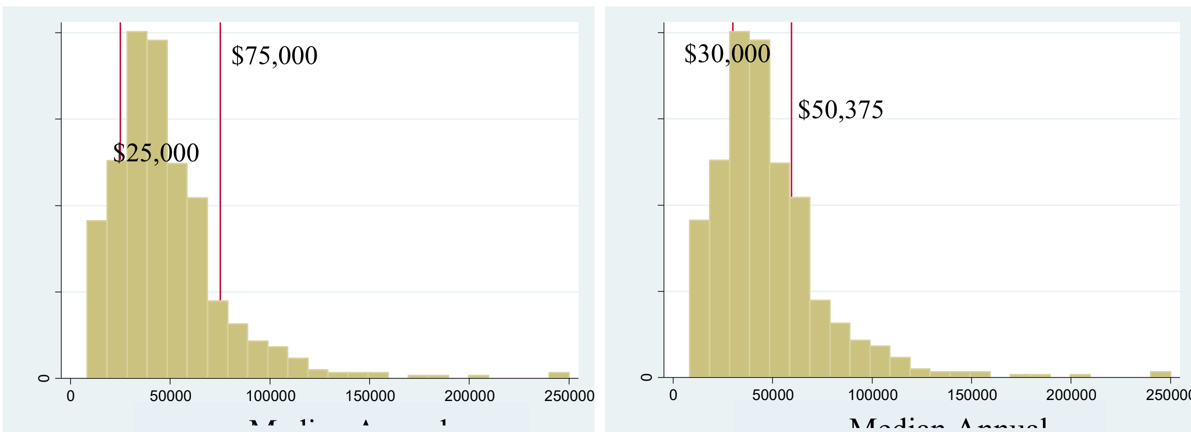


Table A-12. Sensitivity Analysis for Dichotomizing Median Annual Household Income

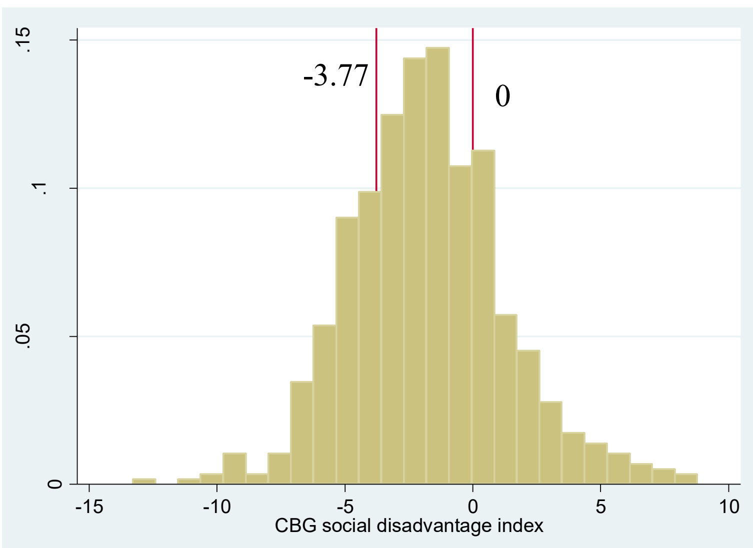
Demographic	Alcohol Outlet Type					
	On Premise		Off Premise		LBD-7	
	Mean	t	Mean	t	Mean	t
Low Income						
Less than $25,000 (n=105)	18.81	-0.23	23.84	-4.11***	22.55	-1.70
$25,000 or more (n=494)	18.36		17.82		19.94	
Low Income						
Less than $30,000 (n=142)	18.77	-0.25	23.00	-3.80***	22.13	-1.54
$30,000 or more (n=457)	18.33		17.60		19.86	
High Income						
$75,000 or more (n=126)	29.06	-3.79***	15.50	2.78**	32.12	-3.64***
Less than $75,000 (n=527)	16.99		19.34		18.79	
High Income						
$59,375 or more (n=204)	26.08	-3.53	18.29	0.24	25.16	-2.72**
Less than $59.375 (n=527)	15.88		19.08		18.80	

Social Disadvantage. The analysis used quartiles to dichotomize the social disadvantage index. Using ACS data, the social disadvantage index was calculated as follows:

([(% female-headed households/10) + (% families living in poverty/10)] – [(% owner-occupied housing/10) + (% adults with college degree/10)]) / 4

Each unit increase in the social disadvantage index corresponds to a 10% increase in the two disadvantage items (i.e., female-headed households and families living in poverty) and a 10% decrease in the two advantage items (i.e., owner-occupied housing and adults with college degree) [219]. The only meaningful value of the social disadvantage index is 0. CBGs with a negative social disadvantage index are those that have more advantage (i.e., owner-occupied housing, percent of adults with college degrees) than disadvantage (i.e., percent of families living in poverty, percent female-headed households). The 75th percentile equaled 0.

Figure A-28. Histogram of Social Disadvantage Index



NOTE: Social disadvantage is calculated using percent female-headed households, percent of families living in poverty, percent owner-occupied housing, and percent of adults aged 25 of older with a college degree. Each unit increase in the social disadvantage index corresponds to a 10% increase in the two disadvantage items (i.e., female-headed households and families living in poverty) and a 10% decrease in the two advantage items (i.e., owner-occupied housing and adults with college degree)

Upon closer examination, the analysis noted a complex association between alcohol outlet distribution and markers of disadvantage. In particular, on-premise and LBD-7 outlets had greater access in areas with some markers of advantage (e.g., low unemployment, low female-headed households, low percent living in poverty, and high home values) but also markers of disadvantage (e.g., home ownership and the social disadvantage index). Off-premise outlets had consistently had greater access in areas that were disadvantaged. Thus, the analysis concluded that advantage could not be simply summarized and dropped the measure from the analysis.

Table A-13. Dichotomizing Social Disadvantage Index

Demographic	Alcohol Outlet Type					
	On Premise		Off Premise		LBD-7	
	Mean	t	Mean	t	Mean	t
Measures of Advantage						
High Advantage on Index (<-3.77)						
Lowest quartile of index (n=151)	13.62	2.82**	16.54	2.65*	15.69	4.43***
Not lowest quartile of index (n=448)	20.06		19.67		21.98	
High Home Ownership (≥66.9%)						
Home ownership (n=153)	13.77	2.78**	13.07	6.25***	14.65	4.61***
Not high home ownership (n=446)	20.04		20.87		22.37	
Low Unemployment (<28%)						
Unemployment (n=156)	28.08	-4.59***	17.37	1.44	29.04	-4.87
Unemployment (n=443)	15.04		19.41		17.35	
Low Female-Headed Households (<22.9%)						
Low percent female-headed households (n=149)	33.11	-6.38***	20.92	-0.83	29.61	-4.89***
Not low percent female-headed households (n=450)	13.8		18.20		17.34	
Low poverty (<4%)						
Low poverty (n=149)	24.38	-3.28**	19.48	-0.25	22.92	-1.55
Not low poverty (n=450)	16.47		18.68		19.56	
High Home Values (≥$201,000)						
High home value (n=129)	29.58	-7.11***	21.77	-1.76	28.92	-6.37***
Not high home value (n=470)	12.81		17.42		16.09	
Measures of Disadvantage						
Low Advantage on Index						
Index at least 0 (n=152)	28.46	-5.30***	21.74	-1.19	26.21	-3.52***
Index less than 0 (n=447)	15.03		17.91		18.42	
Low Home Ownership (<29.6%)						
Low home ownership (n=150)	24.29	-3.49***	24.61	-2.36*	24.20	-2.70**
Not low ownership (n=449)	16.48		19.96		19.12	
High Unemployment (≥ 48%)						
High unemployment (n=134)	14.92	2.85**	21.18	-2.10*	18.05	2.23*
Not high unemployment (n=465)	19.45		18.21		21.07	
High Percent Female-Head Households (≥36.2%)						
High female-headed households (n=167)	13.44	4.97***	21.51	-2.35*	18.56	1.66
Not high female-headed households (n=432)	20.01		18.05		20.97	
High Poverty (≥30.3%)						
High poverty (n=140)	18.21	0.19	23.65	-4.32***	22.72	-1.98
Not high poverty (n=459)	18.51		17.42		19.69	
Low Home Value (<$90,500)						
Low home value (n=201)	13.61	4.83***	23.17	-3.69***	20.54	0.48
Not low home value (n=398)	19.76		17.70		19.87	

Figures A-29 through A-33 show lowess smoothers for the alcohol outlet access variables and the five measures of violent crime (i.e., total violent crime [Figure A-29], homicide [Figure A-30], aggravated assault [Figure A-31], sexual assault [Figure A-32], and robbery [Figure A-33]). The association between alcohol outlet access and violent crime appears roughly linear. However, there may be slight non-linearity in the association between alcohol outlet access and sexual assault exposure (see Figure A-32).

Figure A-29. Lowess Smoothers for Alcohol Outlet Access Variables and Spatial Access Violent Crime using 62 Nearest Crimes

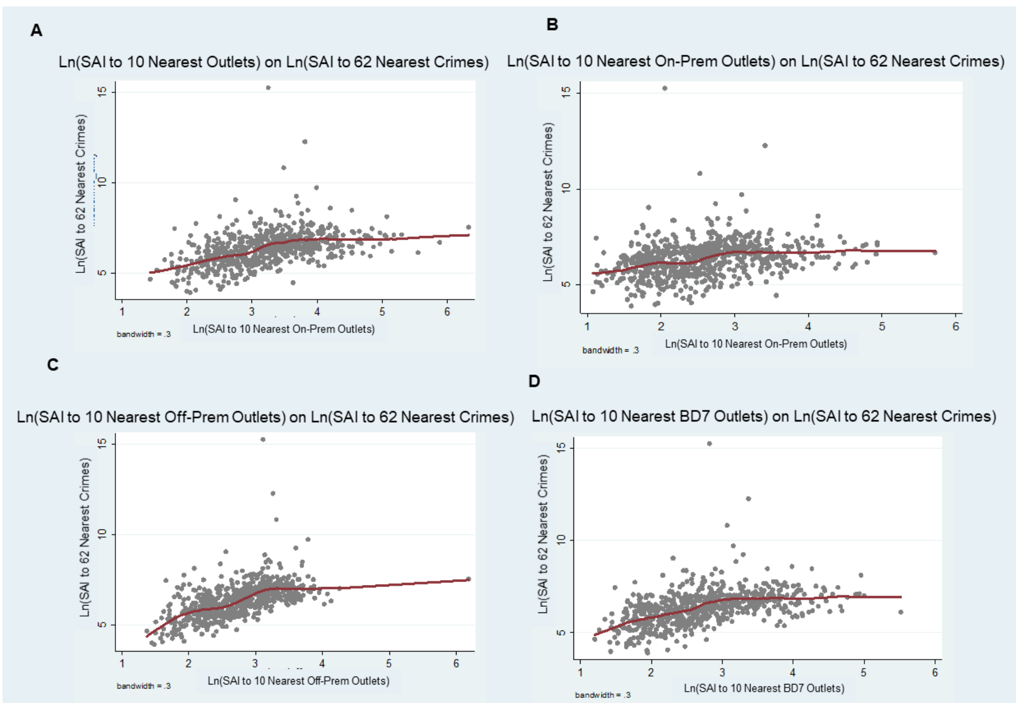


Figure A-30. Lowess Smoothers for Alcohol Outlet Access Variables and Spatial Access Violent Crime using 10 Nearest Homicides

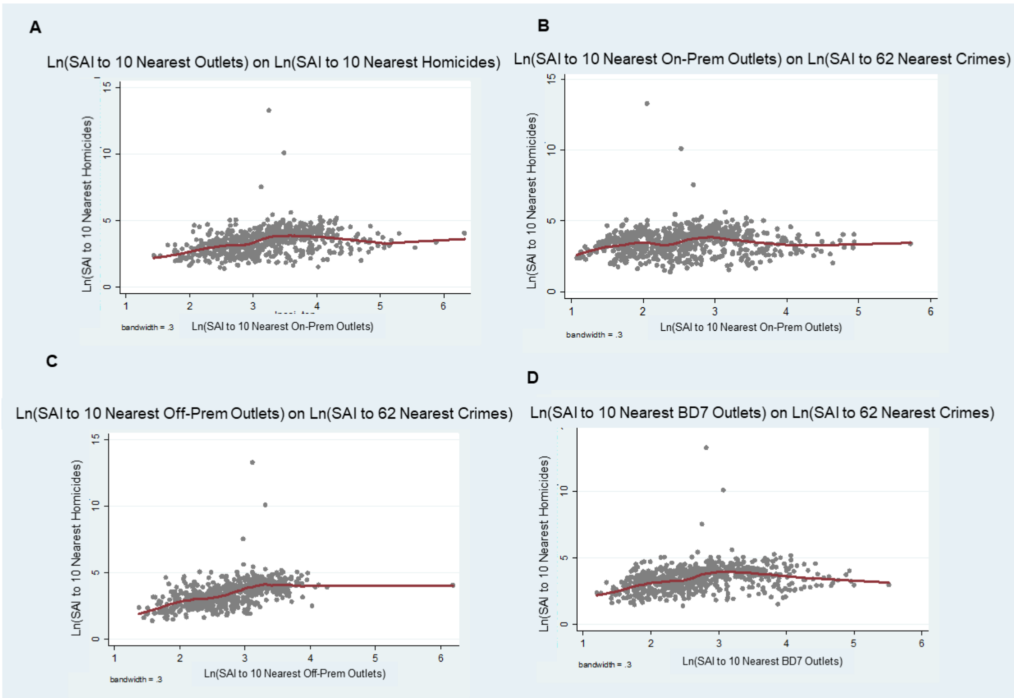


Figure A-31. Lowess Smoothers for Alcohol Outlet Access Variables and Spatial Access Violent Crime using 30 Nearest Assaults

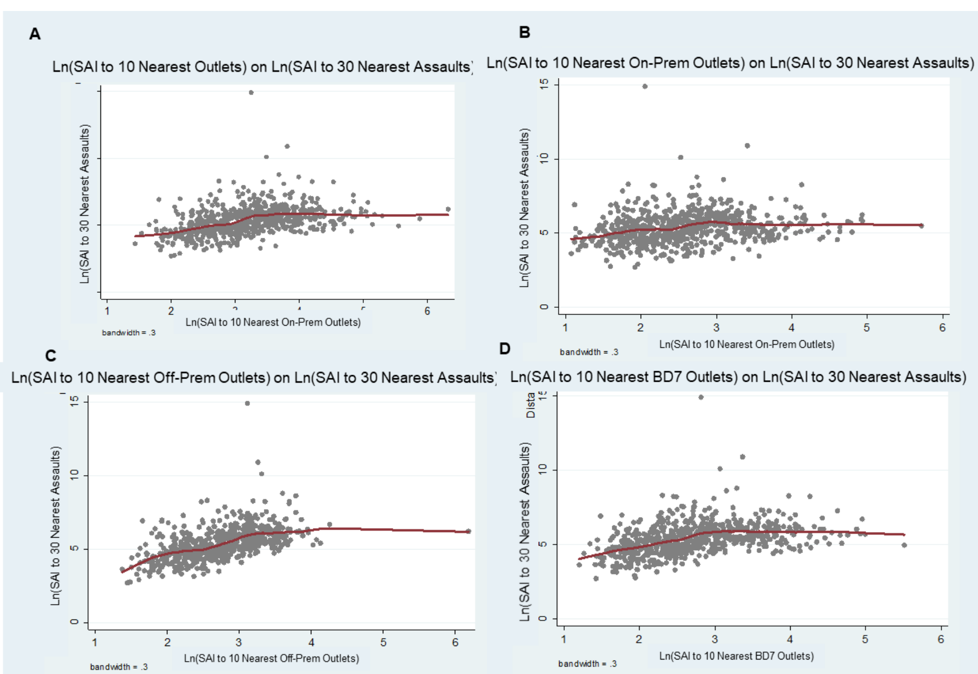


Figure A-32. Lowess Smoothers for Alcohol Outlet Access Variables and Spatial Access Violent Crime using 10 Nearest Sexual Assaults

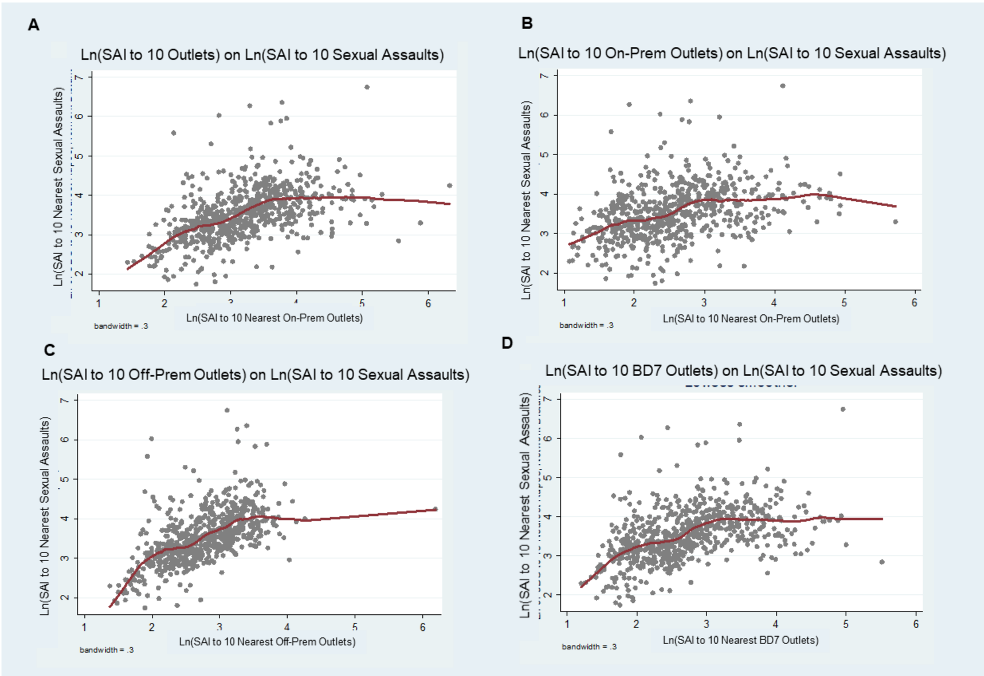


Figure A-33. Lowess Smoothers for Alcohol Outlet Access Variables and Spatial Access Violent Crime using 25 Nearest Robberies

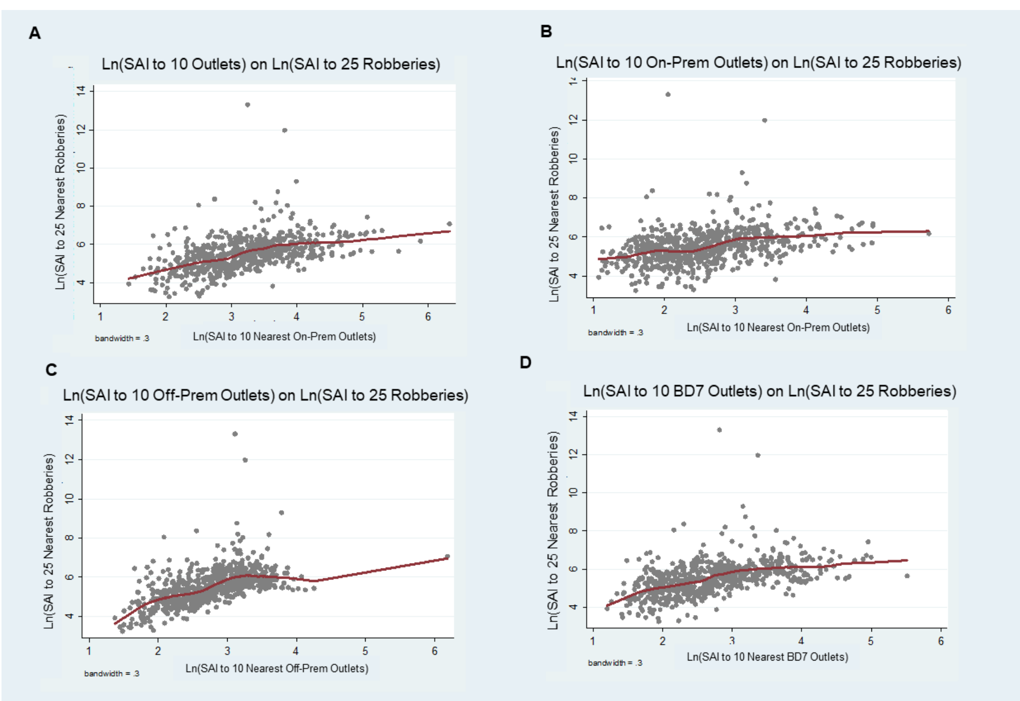


Figure A-34 show quantile-normal plots for the alcohol outlet access and violent crime exposure variables. The variables appear to all be roughly log-normal, though some (e.g., sexual assault) may have some non-linearity in the tails of the distribution.

Figure A-34. Quantile-Normal Plots for Alcohol Outlet Access and Violent Crime Exposure Variables

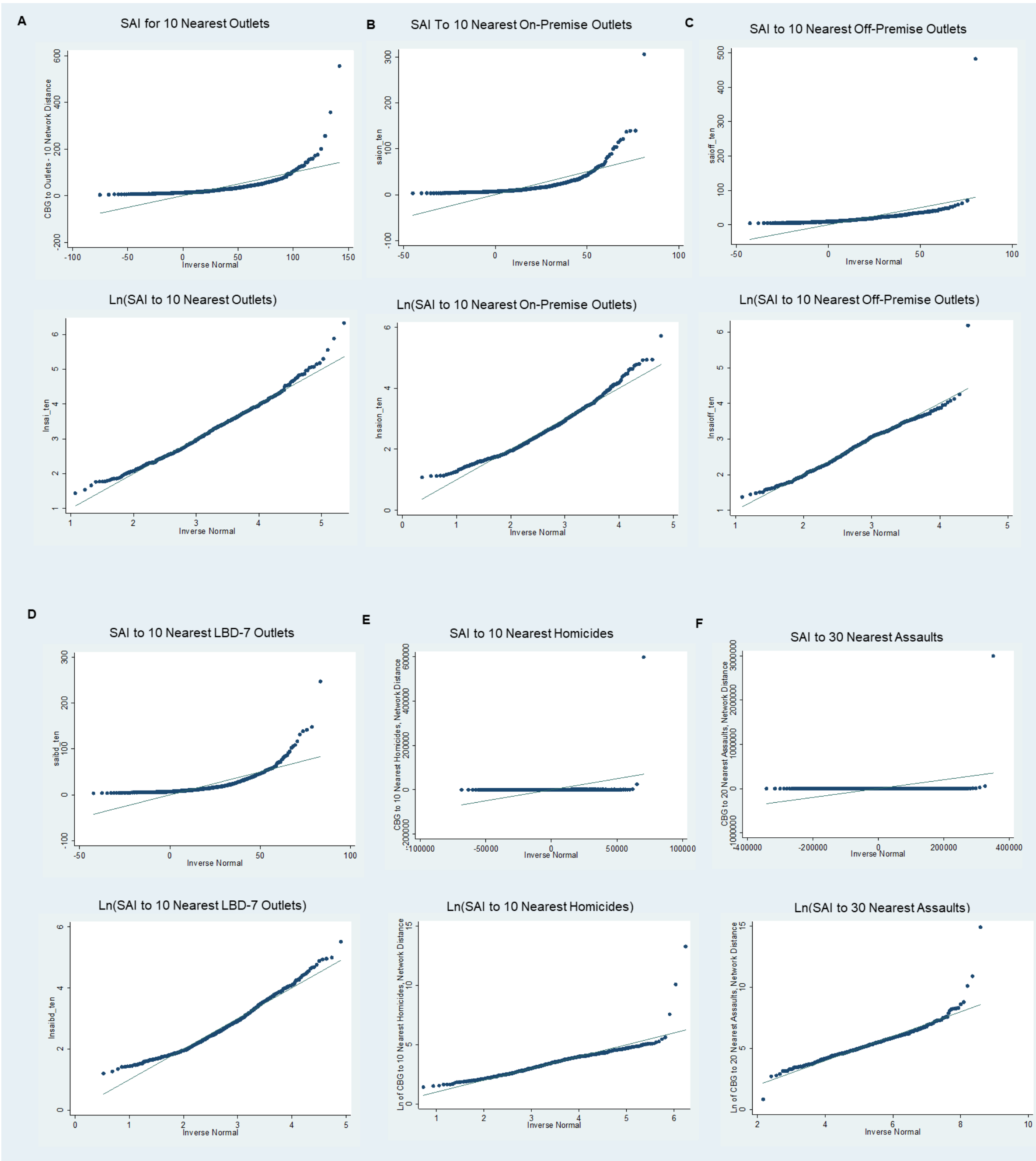
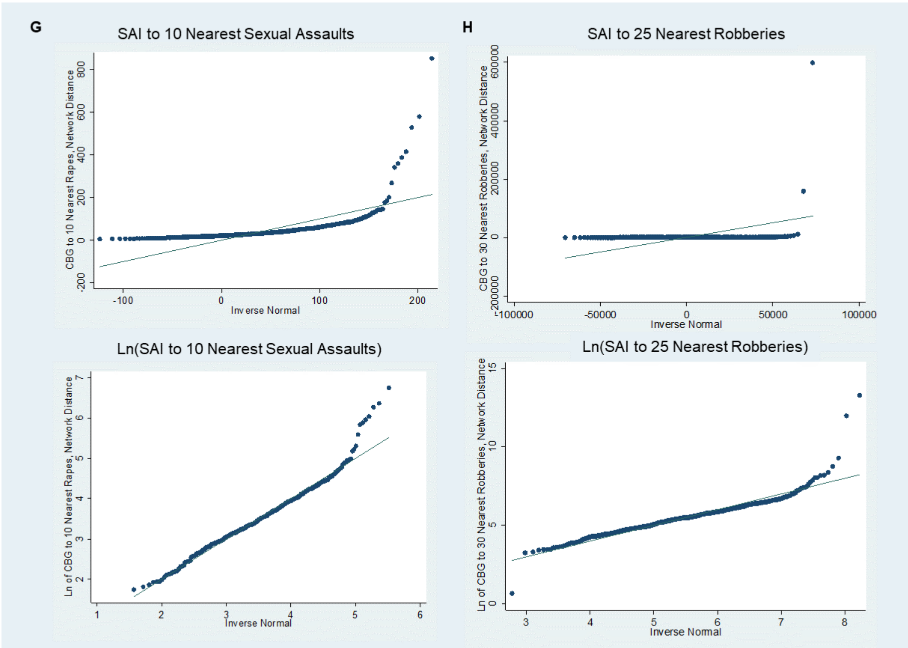


Figure A-34. Quantile-Normal Plots for Alcohol Outlet Access and Violent Crime Exposure Variables (Continued)



Sensitivity Analyses

High-Density Alcohol Outlet Variable

Tables A-14 and A-15 show the results of the analyses that included the high- alcohol outlet density indicator variable. The alcohol outlet cluster variable was significant in more of the models (2 out of 5) with seven outlets in the choice set than in the models with 10 outlets (1 out of 5). This provides some evidence to support that larger choice set sizes are able to detect clustering. The high-density indicator remained significant for the off-premise outlets, which is likely because there are the fewest of this type of outlet (n=264). This means the outlets are likely more dispersed across the city and an even larger choice set size is required to detect clustering.

Table A-14. Regression Results Including Indicator for High Alcohol Outlet Density CBGs with a Choice Set Size of Seven Outlets

Variable	Total Alcohol Outlet SAI	On-Premise Alcohol Outlet SAI	Off-Premise Alcohol Outlet SAI	LBD-7 SAI	Three Outlet Type SAIs
	Model 1	Model 2	Model 3	Model 4	Model 5
Total alcohol outlet SAI[a]	0.46***				
On-premise alcohol outlet SAI[b]		0.30***			-0.06
Off-premise alcohol outlet SAI[c]			0.46***		0.26***
LBD-7 alcohol outlet SAI[d]				0.45***	0.36***
Drug arrests	0.02**	0.03***	0.02**	0.02*	0.01
Percent African American	0.46***	0.74***	0.46***	0.75***	0.64***
Median annual household income	-0.04**	-0.03*	-0.04**	-0.03*	-0.03**
Owner-occupied housing	-0.01*	-0.01**	-0.01*	-0.01**	-0.01*
Population density	0.03***	0.03***	0.03***	0.03***	0.02***
Alcohol cluster indicator	0.23*	0.14	0.23*	0.02	0.05

SAI spatial accessibility index
[a]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest alcohol outlets.
[b]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest on-premise alcohol outlets.
[c]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest off-premise alcohol outlets.
[d]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest LBD-7 alcohol outlets. LBD-7 outlets are outlets that are permitted to sell alcohol for on- and/or off-premise consumption.

Table A-15. Regression Results Including Indicator for High Alcohol Outlet Density CBGs with a Choice Set Size of 10 Outlets

Variable	Total Alcohol Outlets	On-Premise Alcohol Outlets	Off-Premise Alcohol Outlets	LBD-7 Alcohol Outlets	All Alcohol Outlets
	Model 1	Model 2	Model 3	Model 4	Model 5
Total alcohol outlet SAI[a]	0.45***				
On-premise alcohol outlet SAI[b]		0.33***			-0.08
Off-premise alcohol outlet SAI[c]			0.50***		0.28**
LBD-7 alcohol outlet SAI[d]				0.48***	0.40***
Drug arrests	0.02**	0.03***	0.02**	0.02*	0.01
Percent African American	0.73***	0.75***	0.44***	0.75***	0.62***
Median annual household income	-0.03**	-0.04**	-0.04**	-0.03*	-0.03**
Owner-occupied housing	-0.01**	-0.01**	-0.01*	-0.01**	-0.01*
Population density	0.03***	0.03***	0.03***	0.03***	0.02***
Alcohol cluster indicator	0.08	0.12	0.21*	>-0.01	0.04

SAI spatial accessibility index
[a]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest alcohol outlets.
[b]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest on-premise alcohol outlets.
[c]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest off-premise alcohol outlets.
[d]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest LBD-7 alcohol outlets. LBD-7 outlets are outlets that are permitted to sell alcohol for on- and/or off-premise consumption.

Homicide Choice Set Size

Table A-16 summarizes the results from the sensitivity analysis that compares variables for homicide exposure with choice set sizes ranging from 4 to 10. Overall, the alcohol outlet access variables do not differ in levels of significance as choice set size increases. However, the measures of association appear to decrease slightly with larger choice set sizes.

Table A-16. Sensitivity Analysis for Homicide Choice Set Size

	Set Size of 4 Homicides				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI[a]	0.39***				
On-premise alcohol outlet SAI[b]		0.25***			-0.17*
Off-premise alcohol outlet SAI[c]			0.48***		0.33***
LBD-7 alcohol outlet SAI[d]				0.39***	0.36***
Drug arrests	0.02*	0.03***	0.02**	0.02*	0.01
Percent African American	1.39***	1.36***	1.10***	1.42***	1.21***
Median annual household income	-0.02	-0.02	-0.02	-0.02	-0.02
Owner-occupied housing	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
Population density	0.02***	0.02***	0.02***	0.02***	0.02***
	Set Size of 5 Homicides				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.25***			-0.17*
Off-premise alcohol outlet SAI			0.48***		0.33***
LBD-7 alcohol outlet SAI				0.39***	0.35***
Drug arrests	0.02**	0.03***	0.02**	0.02*	0.02*
Percent African American	1.38***	1.34***	1.09***	1.40***	1.19***
Median annual household income	-0.01	-0.02	-0.02	-0.01	-0.02
Owner-occupied housing	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
Population density	0.02***	0.02***	0.02***	0.02***	0.02***
	Set Size of 6 Homicides				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.25***			-0.16*
Off-premise alcohol outlet SAI			0.48***		0.33***
LBD-7 alcohol outlet SAI				0.38***	0.34***
Drug arrests	0.02**	0.03***	0.02**	0.02**	0.02*
Percent African American	1.36***	1.33***	1.08***	1.38***	1.18***
Median annual household income	-0.01	-0.02	-0.02	-0.01	-0.01
Owner-occupied housing	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
Population density	0.02***	0.02***	0.02***	0.02***	0.02***
	Set Size of 7 Homicides				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.25***			-0.16*
Off-premise alcohol outlet SAI			0.48***		0.34***
LBD-7 alcohol outlet SAI				0.38***	0.33***
Drug arrests	0.02**	0.03***	0.02**	0.02**	0.02*
Percent African American	-0.01***	1.32***	1.07***	1.37***	1.17***

Median annual household income	-0.01	-0.01	-0.02	-0.01	-0.01
Owner-occupied housing	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
Population density	0.02***	0.02***	0.02***	0.02***	0.02***
	Set Size of 8 Homicides				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.25***			-0.15*
Off-premise alcohol outlet SAI			0.48***		0.34***
LBD-7 alcohol outlet SAI				0.38***	0.33***
Drug arrests	0.02**	0.03***	0.02**	0.02**	0.02*
Percent African American	1.34***	1.31***	1.06***	1.36***	1.16***
Median annual household income	-0.01	-0.01	-0.01	-0.01	-0.01
Owner-occupied housing	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
Population density	0.02***	0.02***	0.02***	0.02***	0.02***
	Set Size of 9 Homicides				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.37***				
On-premise alcohol outlet SAI		0.25***			-0.15*
Off-premise alcohol outlet SAI			0.48***		0.34***
LBD-7 alcohol outlet SAI				0.38***	0.32***
Drug arrests	0.02**	0.03***	0.02***	0.02**	0.01*
Percent African American	1.33***	1.30***	1.05***	1.35***	1.15***
Median annual household income	-0.01	-0.01	-0.01	-0.01	-0.01
Owner-occupied housing	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
Population density	0.02***	0.02***	0.02***	0.02***	0.01***
	Set Size of 10 Homicides				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.37***				
On-premise alcohol outlet SAI		0.25***			-0.14*
Off-premise alcohol outlet SAI			0.48***		0.34***
LBD-7 alcohol outlet SAI				0.37***	0.32***
Drug arrests	0.02**	0.03***	0.02***	0.02**	0.01*
Percent African American	1.32***	1.30***	1.04***	1.34***	1.14***
Median annual household income	-0.01	-0.01	-0.01	-0.01	-0.01
Owner-occupied housing	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
Population density	0.02***	0.02***	0.02***	0.02***	0.01***

SAI spatial accessibility index
[a]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest alcohol outlets.
[b]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest on-premise alcohol outlets.
[c]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest off-premise alcohol outlets.
[d]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest LBD-7 alcohol outlets. LBD-7 outlets are outlets that are permitted to sell alcohol for on- and/or off-premise consumption.

Sexual Assault Choice Set Size

Table A-17 shows the results of a sensitivity analysis to compare different choice set sizes for the sexual assault exposure variable. The results from models 1-4 appear relatively stable across the different choice set sizes. However, the three alcohol outlet SAIs increase in levels of significance and the regression coefficients changed slightly (the on-premise SAI increased, off-premise SAI stayed stable, and LBD-7 SAI decreased slightly)

Table A-17. Sensitivity Analysis for Sexual Assault Choice Set Size

	Set Size of 2 Sexual Assaults				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI[a]	0.38***				
On-premise alcohol outlet SAI[b]		0.33***			0.12
Off-premise alcohol outlet SAI[c]			0.41***		0.19*
LBD-7 alcohol outlet SAI[d]				0.34***	0.16*
Drug arrests	0.01	0.02**	0.02**	0.02*	0.01
Percent African American	0.38***	0.46***	0.09	0.37**	0.37**
Median annual household income	-0.04**	-0.04**	-0.04**	-0.04**	-0.04**
Owner-occupied housing	-0.01**	-0.01**	-0.01**	-0.01***	-0.01**
Population density	0.02***	0.02***	0.02***	0.02***	0.02***
	Set Size of 3 Sexual Assaults				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.34***			0.13
Off-premise alcohol outlet SAI			0.41***		0.19*
LBD-7 alcohol outlet SAI				0.34***	0.15*
Drug arrests	0.01*	0.02**	0.02**	0.02*	0.01*
Percent African American	0.38***	0.46***	0.09	0.37***	0.37**
Median annual household income	-0.04**	-0.04**	-0.04***	-0.04**	-0.04**
Owner-occupied housing	-0.01**	-0.01***	-0.01**	-0.01***	-0.01**
Population density	0.02***	0.02***	0.02***	0.02***	0.01***
	Set Size of 4 Sexual Assaults				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.34***			0.14*
Off-premise alcohol outlet SAI			0.41***		0.19**
LBD-7 alcohol outlet SAI				0.35***	0.16*
Drug arrests	0.01*	0.02**	0.02**	0.01*	0.01*
Percent African American	0.37***	0.45***	0.08	0.35***	0.37***
Median annual household income	-0.04***	-0.04***	-0.04***	-0.04**	-0.04***
Owner-occupied housing	-0.01***	-0.01***	-0.01**	-0.01***	-0.01**
Population density	0.01***	0.02***	0.02***	0.02***	0.01***
	Set Size of 5 Sexual Assaults				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.34***			0.14*
Off-premise alcohol outlet SAI			0.41***		0.19**
LBD-7 alcohol outlet SAI				0.35***	0.15*
Drug arrests	0.01*	0.02***	0.02**	0.01*	0.01*
Percent African American	0.36***	0.45***	0.07	0.35***	0.37***
Median annual household income	-0.04***	-0.04***	-0.04***	-0.04***	-0.04***
Owner-occupied housing	-0.01***	-0.01***	-0.01**	-0.01***	-0.01**
Population density	0.01***	0.02***	0.02***	0.02***	0.01***
	Set Size of 6 Sexual Assaults				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.34***			0.14*
Off-premise alcohol outlet SAI			0.41***		0.19**
LBD-7 alcohol outlet SAI				0.35***	0.15*
Drug arrests	0.01*	0.02***	0.02**	0.01*	0.01*
Percent African American	0.37***	0.46***	0.08	0.36***	0.37***

Median annual household income	-0.04***	-0.04***	-0.04***	-0.04***	-0.04***
Owner-occupied housing	-0.01***	-0.01***	-0.01**	-0.01***	-0.01**
Population density	0.01***	0.02***	0.02***	0.02***	0.01***
	Set Size of 7 Sexual Assaults				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.34***			0.14*
Off-premise alcohol outlet SAI			0.42***		0.19**
LBD-7 alcohol outlet SAI				0.35***	0.15*
Drug arrests	0.01*	0.02***	0.02**	0.01*	0.01*
Percent African American	0.37***	0.46***	0.08	0.36***	0.37***
Median annual household income	-0.03***	-0.04***	-0.04***	-0.03**	-0.04***
Owner-occupied housing	-0.01***	-0.01***	-0.01***	-0.01***	-0.01**
Population density	0.01***	0.02***	0.02***	0.02***	0.01***
	Set Size of 8 Sexual Assaults				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.35***			0.14**
Off-premise alcohol outlet SAI			0.42***		0.19**
LBD-7 alcohol outlet SAI				0.35***	0.15**
Drug arrests	0.01*	0.02***	0.02**	0.01*	0.01*
Percent African American	0.37***	0.46***	0.08	0.36***	0.38***
Median annual household income	-0.03***	-0.03***	-0.04***	-0.03**	-0.03***
Owner-occupied housing	-0.01***	-0.01***	-0.01***	-0.01***	-0.01**
Population density	0.01***	0.02***	0.02***	0.01***	0.01***
	Set Size of 9 Sexual Assaults				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.35***			0.15**
Off-premise alcohol outlet SAI			0.42***		0.19**
LBD-7 alcohol outlet SAI				0.35***	0.15**
Drug arrests	0.01*	0.02***	0.02**	0.01*	0.01*
Percent African American	0.37***	0.47***	0.08	0.36***	0.38***
Median annual household income	-0.03**	-0.03***	-0.03***	-0.03**	-0.03***
Owner-occupied housing	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
Population density	0.01***	0.02***	0.02***	0.01***	0.01***
	Set Size of 10 Sexual Assaults				
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Total alcohol outlet SAI	0.38***				
On-premise alcohol outlet SAI		0.35***			0.15**
Off-premise alcohol outlet SAI			0.42***		0.20***
LBD-7 alcohol outlet SAI				0.35***	0.14**
Drug arrests	0.01*	0.02***	0.02***	0.01*	0.01*
Percent African American	0.37***	0.47***	0.09	0.37***	0.38***
Median annual household income	-0.03**	-0.03***	-0.03***	-0.03**	-0.03***
Owner-occupied housing	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
Population density	0.01***	0.02***	0.02***	0.01***	0.01***

SAI spatial accessibility index

[a]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest alcohol outlets.

[b]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest on-premise alcohol outlets.

[c]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest off-premise alcohol outlets.

[d]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest LBD-7 alcohol outlets. LBD-7 outlets are outlets that are permitted to sell alcohol for on- and/or off-premise consumption.

Sensitivity Analysis for Outlet Type

Table A-18. Sensitivity Analysis for Determining How to Categorize Outlet Types

Variable	On-Premise Only	On-Premise with LBD-7s ≥50% of Floor Space	Off-Premise Only	Off-Premise with LBD-7s <50% Floor Space	Off-Premise with All LBD-7s	LBD-7s Only
Total Alcohol Outlet SAI	0.29***	0.39***	0.46***	0.51***	0.51***	0.48***
Drug arrests	0.02*	0.02	0.02	0.01	0.01	0.01
Percent African American	0.98***	1.07***	0.70***	0.79***	0.92***	1.02***
Vacant housing	0.12	0.09	0.09	0.08	0.07	0.07
Median annual household income	-0.05*	-0.05*	-0.04*	-0.04*	-0.05*	-0.05*
Percent population aged 18-35	0.38	0.38	0.29	0.24	0.26	0.35
Population density	0.04***	0.03***	0.04***	0.03***	0.03***	0.03***
High-density cluster	0.09	0.02	0.17	0.08	0.02	-0.05

*p<0.05, **p<0.01, ***p<0.001
SAI spatial accessibility index
NOTE: LBD-7s outlets are outlets that are permitted to sell alcohol for on- and/or off-premise consumption.

Analysis

Multicollinearity occurs when two or more covariates are correlated to the extent that one variable can predict the value of the other, and it can reduce the regression model's stability. Thus, the analysis investigated correlations and variance inflation factors (VIFs) to determine whether multicollinearity inflated the variance in the regression coefficients and produced unstable estimates. The alcohol outlet correlations have moderate associations with one another (see Table A-19). The correlation is strongest between the on-premise and LBD-7 SAIs (r=0.82). All VIFs were less than 5, suggesting that the regression coefficients were not unstable (see Table A-20).

Table A-19. Correlations between Regression Variables

Variable	Variable								
	Total SAI	**On-premise SAI**	**Off-premise SAI**	**LBD-7 SAI**	**Drug arrests**	**Percent African American**	**Income**	**Owner-occupied housing**	**Population density**
Total alcohol outlet SAI[a]	1								
On-premise alcohol outlet SAI[b]	0.87	1							
Off-premise alcohol outlet SAI[c]	0.82	0.59	1						
LBD-7 alcohol outlet SAI[d]	0.91	0.82	0.68	1					
Drug arrests	0.24	0.06	0.33	-0.24	1				
Percent African American	-0.22	-0.42	0.13	-0.24	0.40	1			
Median annual household income	-0.05	0.10	-0.24	-0.03	-0.40	-0.57	1		
Owner-occupied housing	-0.24	-0.24	-0.31	-0.23	-0.22	-0.18	0.55	1	
Population density	0.42	0.36	0.40	0.40	0.06	0.03	-0.10	-0.23	1

NOTE: All SAIs and drug arrests were transformed using the natural logarithm before estimating these correlations.
[a]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest alcohol outlets.
[b]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest on-premise alcohol outlets.
[c]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest off-premise alcohol outlets.
[d]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest LBD-7 alcohol outlets. LBD-7 outlets are outlets that are permitted to sell alcohol for on- and/or off-premise consumption.

Table A-20. Variance Inflation Factors for Regression Covariates by Model

Variable	Model 1	Model 2	Model 3	Model 4	Models 5-9
Total alcohol outlet SAI[a]	1.62				
On-premise alcohol outlet SAI[b]		1.68			4.01
Off-premise alcohol outlet SAI[c]			1.49		2.59
LBD-7 alcohol outlet SAI[d]				1.60	3.93
Drug arrests	1.43	1.34	1.37	1.45	1.46
Percent African American	1.88	2.15	1.57	1.90	2.39
Median annual household income	1.80	1.80	1.80	1.80	1.80
Owner-occupied housing	1.36	1.36	1.42	1.35	1.43
Population density	1.27	1.21	1.21	1.25	1.29

[a]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest alcohol outlets.
[b]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest on-premise alcohol outlets.
[c]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest off-premise alcohol outlets.
[d]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest LBD-7 alcohol outlets. LBD-7 outlets are outlets that are permitted to sell alcohol for on- and/or off-premise consumption.

Figure A-35. Choropleth Map of Access to Alcohol Outlets and Violent Crime, Baltimore City 2012-2016

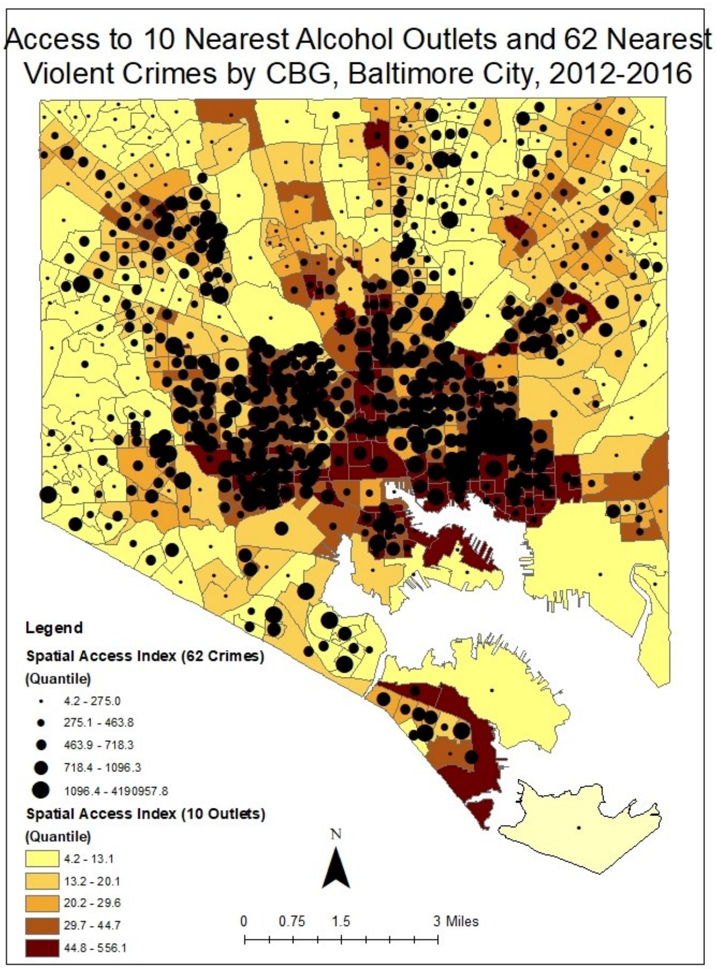


Figure A-36. Choropleth Maps of Violent Crime Exposure Indices and Industrial Areas, Baltimore City 2012-2016

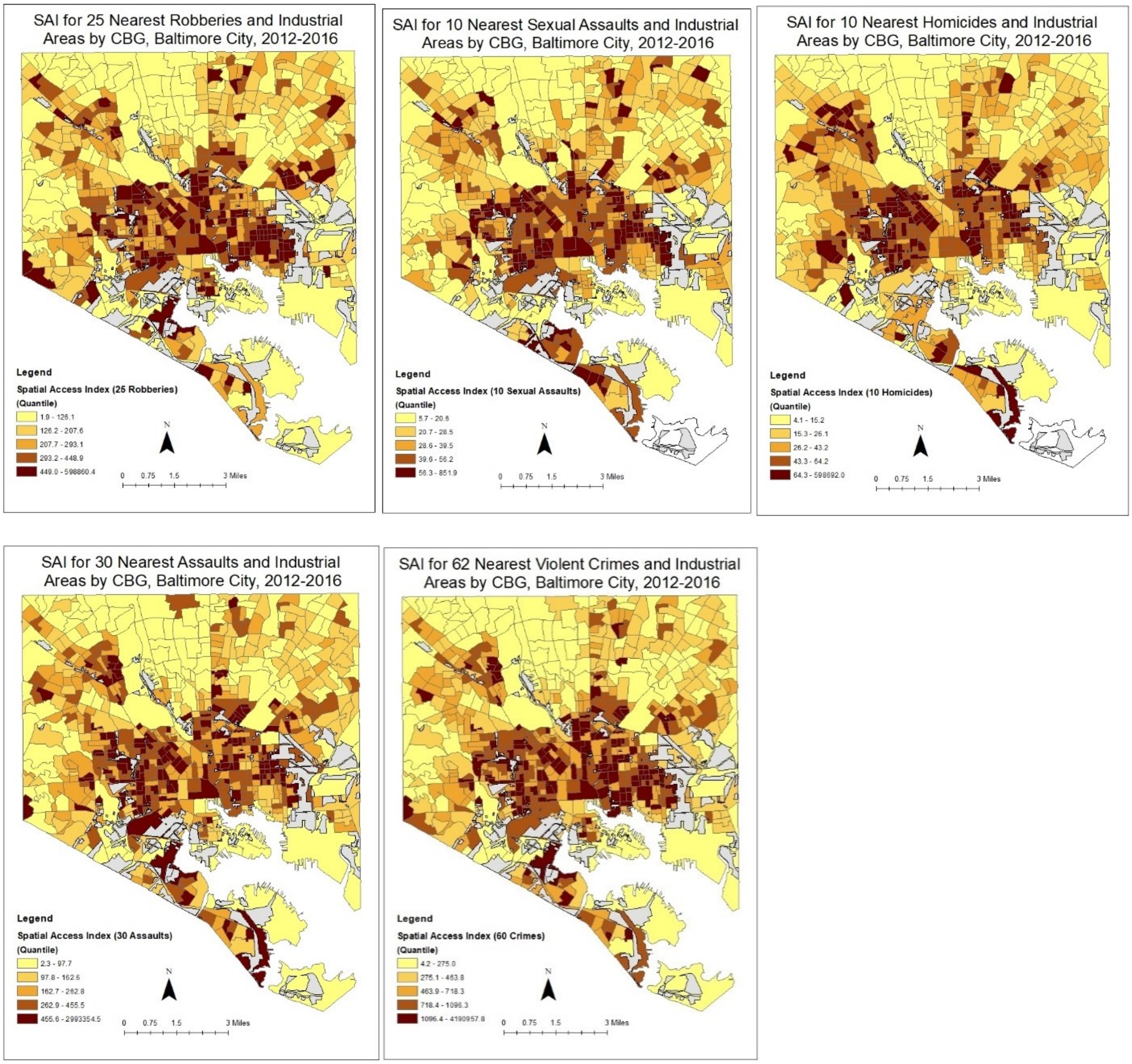


Table A-21. Linear Regression Results for Model of Total Alcohol Outlet Access on Total Violent Crime with Lag Term for Alcohol Outlet Spatial Accessibility

Variable	Model 1 All Outlets		
	β	SE	P Value
Total alcohol outlet SAI[a]	2.22	0.19	<0.001
Drug arrests	0.05	0.02	<0.01
Percent African American	28.94	2.80	<0.001
Median annual household income	0.01	0.03	0.66
Owner-occupied housing	-0.01	0.01	0.44
Population density	<0.01	<0.01	<0.001
Alcohol outlet SAI lag	-0.82	0.23	<0.001
Moran's I	0.07		<0.01

[a]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest alcohol outlets.

Table A-22. Moran's I for Regression Models with Lag Terms for Covariates

	Moran's I	P Value
Lagged term: Drug arrests		
Total alcohol outlet SAI[a]	<0.01	0.04
On-premise alcohol outlet SAI[b]	0.07	<0.01
Off-premise alcohol outlet SAI[c]	0.07	<0.01
LBD-7 alcohol outlet SAI[d]	0.05	0.02
Lagged term: Percent African American		
Total alcohol outlet SAI	0.12	<0.001
On-premise alcohol outlet SAI	0.08	<0.01
Off-premise alcohol outlet SAI	0.08	<0.01
LBD-7 alcohol outlet SAI	0.05	0.02
Lagged term: Median annual household income		
Total alcohol outlet SAI	0.12	<0.001
On-premise alcohol outlet SAI	0.07	<0.01
Off-premise alcohol outlet SAI	0.07	<0.001
LBD-7 alcohol outlet SAI	0.05	0.03
Lagged term: Owner-occupied housing		
Total alcohol outlet SAI	0.12	<0.001
On-premise alcohol outlet SAI	0.08	<0.01
Off-premise alcohol outlet SAI	0.08	<0.001
LBD-7 alcohol outlet SAI	0.05	0.02
Lagged term: Population density		
Total alcohol outlet SAI	0.12	<0.001
On-premise alcohol outlet SAI	0.07	<0.01
Off-premise alcohol outlet SAI	0.07	<0.01
LBD-7 alcohol outlet SAI	0.05	0.02

[a]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest alcohol outlets.
[b]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest on-premise alcohol outlets.
[c]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest off-premise alcohol outlets.
[d]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest LBD-7 alcohol outlets. LBD-7 outlets are outlets that are permitted to sell alcohol for on- and/or off-premise consumption.

Table A-23. Linear Regression Results for Model of Alcohol Outlet Access on Total Violent Crime with Lag Term for Alcohol Outlet Spatial Accessibility and by Outlet Type

Variable	Model 2 On-Premise Outlets			Model 3 Off-Premise Outlets			Model 4 LBD-7 Outlets			Model 5 All Outlets		
	β	SE	P Value	β	SE	P Value	β	SE	P Value	β	SE	P Value
On-premise SAI[a]	2.62	0.27	<0.001							1.18	0.32	<0.001
Off-premise SAI[b]				2.56	0.62	<0.001				1.25	0.30	<0.001
LBD-7 SAI[c]							2.63	0.23	<0.001	1.46	0.29	<0.001
Drug arrests	0.09	0.02	<0.001	0.07	0.27	<0.001	0.01	0.02	<0.01	0.05	0.02	0.02
Percent African American	31.00	3.09	<0.001	17.52	0.02	<0.001	27.83	2.83	<0.001	24.23	3.30	<0.001
Median annual household income	0.01	0.03	0.74	>-0.01	2.66	0.82	<0.01	0.03	0.8	<0.01	0.03	0.83
Owner-occupied housing	>-0.01	<0.01	0.21	<0.01	0.03	0.94	>-0.01	0.01	0.12	>-0.01	<0.01	0.54
Population density	<0.01	<0.01	<0.001	<0.01	<0.01	<0.001	<0.01	<0.01	<0.001	<0.01	<0.01	<0.001
On-premise SAI lag	-1.55	0.31	<0.001							-1.28	0.43	<0.01
Off-premise SAI lag				-0.86	0.32	<0.01				-0.37	0.41	0.37
BD-7 SAI lag							-1.46	0.27	<0.001	-0.61	0.39	0.12
Moran's I	0.08		<0.001	0.06		0.01	0.06		0.01	0.06		0.01

SAI spatial accessibility index; SE standard error; Moran's I Moran's Index

[a]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest on-premise alcohol outlets.

[b]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest off-premise alcohol outlets.

[c]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest LBD-7 alcohol outlets. LBD-7 outlets are outlets that are permitted to sell alcohol for on- and/or off-premise consumption.

Table A-24. Linear Regression Results for Model of Alcohol Outlet Access on Total Violent Crime with Lag Term for Alcohol Outlet Spatial Accessibility and by Outlet Type and Crime Type

Variable	Model 6 Homicide			Model 7 Aggravated Assault			Model 8 Rape			Model 9 Robbery		
	β	SE	P Value	β	SE	P Value	β	SE	P Value	β	SE	P Value
On-premise SAI[a]	-0.09	0.12	0.45	<0.01	0.13	0.98	0.28	0.09	<0.01	0.17	0.12	0.17
Off-premise SAI[b]	0.42	0.11	<0.001	0.45	0.12	<0.001	0.29	0.08	<0.001	0.39	0.11	<0.001
LBD-7 SAI[c]	0.34	0.01	<0.01	0.53	0.12	<0.001	0.21	0.08	0.01	0.40	0.11	<0.001
Drug arrests	0.01	1.26	0.07	0.02	0.01	0.02	0.01	0.01	<0.01	0.01	0.01	0.10
Percent African American	12.58	0.01	<0.001	9.29	1.36	<0.001	3.77	0.93	<0.001	5.21	1.23	<0.001
Median annual household income	-0.02	<0.01	0.21	>-0.01	0.01	0.14	-0.02	0.01	<0.01	-0.01	0.01	0.29
Owner-occupied housing	-0.01	<0.01	<0.001	>-0.01	<0.01	<0.01	>-0.01	<0.01	<0.001	>-0.01	<0.01	0.71
Population density	<0.01	<0.01	<0.001	<0.01	<0.01	<0.001	<0.01	<0.01	<0.001	<0.01	<0.01	<0.001
On-premise SAI lag	-0.18	0.16	0.28	-0.27	0.18	0.13	-0.16	0.12	0.18	-0.14	0.16	0.40
Off-premise SAI lag	-0.01	0.16	0.62	-0.13	0.17	0.46	-0.84	0.12	0.47	-0.13	0.15	0.42
LBD-7 SAI lag	0.15	0.15	0.60	<0.01	0.16	0.96	-0.08	0.11	0.45	-0.01	0.15	0.71
Moran's I	0.06		<0.01	0.15		<0.001	0.04		0.05	0.08		<0.001

SAI spatial accessibility index; SE standard error; Moran's I Moran's Index
[a]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest on-premise alcohol outlets.
[b]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest off-premise alcohol outlets.
[c]Calculated as the sum of the inverse network distance from the CBG centroid to the 10 nearest LBD-7 alcohol outlets. LBD-7 outlets are outlets that are permitted to sell alcohol for on- and/or off-premise consumption.

Figure A-37. Leverage by Census Block Group (n=599)

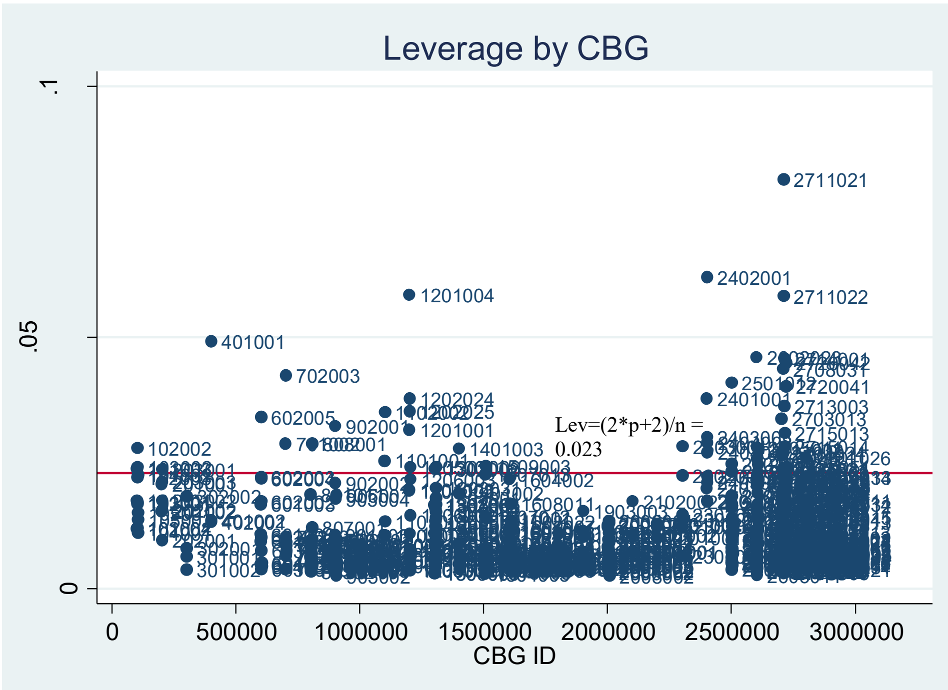


Figure A-38. Cook's Distance by Census Block Group (n=599)

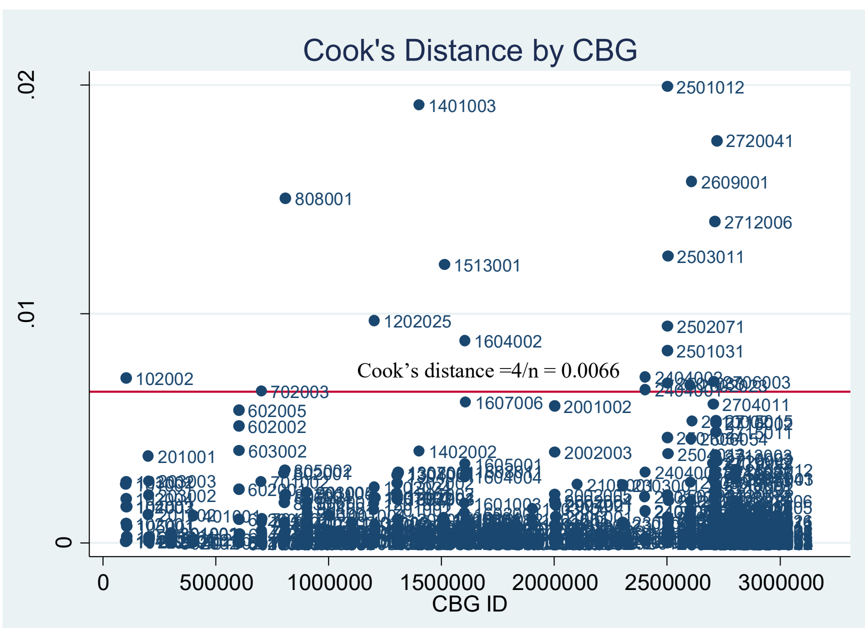


Figure A-39. Studentized Residuals by Census Block Group (n=599)

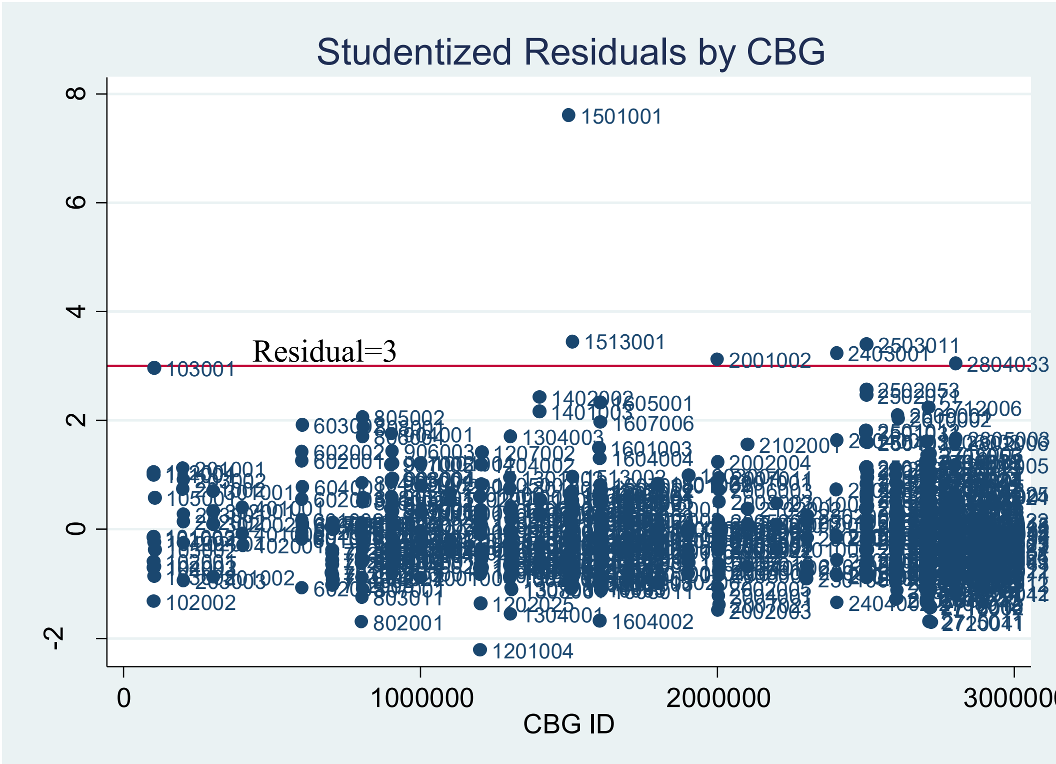


Table A-25. Sensitivity Analysis Comparing CBGs with and without High Leverage, Cook's Distance, and Studentized Residuals

	Ln(SAI to 62 Nearest Crimes)[d]		Ln(SAI to 10 Nearest Alcohol Outlets)[e]		Median Annual Household Income		Percent African American	
	Mean	P value	Mean	P value	Mean	P value	Mean	P value
Leverage[a]								
≥0.023 (n=54)	5.96	<0.01	3.38	0.23	$80,412	<0.001	32.6%	<0.001
<0.023 (n=545)	6.39		3.19		$44,553		69.4%	
Cook's Distance[b]								
≥0.0066 (n=25)	7.54	0.01	3.22	0.98	$50,652	0.61	44.7%	<0.01
<0.0066 (n=574)	6.30		3.21		$47,662		66.9%	
Studentized Residuals[c]								
≥3 (n=7)	10.03	0.01	3.21	0.99	$44,693	0.71	76.6%	0.45
<3 (n=592)	6.31		3.21		$47,823		65.9%	

[a]The value (2*p+2)/n, where p is the number of parameters and n is the sample size, was used to identify CBGs with a high leverage.
[b]The value 4/n, where n is the sample size, was used to identify CBGs with a high Cook's distance.
[c]The value 3 was used to identify CBGs with high studentized residuals.
[d]Calculated as the natural log of the sum of the inverse network distance from the CBG centroid to the 10 nearest alcohol outlets.
[e]Calculated as the natural log of the sum of the inverse network distance from the CBG centroid to the 62 nearest violent crimes.

Table A-26. Sensitivity Analysis for Excluding CBGs with High Leverage, Cook's Distance, or Studentized Residuals

Variable	Model 1 All CBGs			Model 2 No CBGs with High Leverage[a]			Model 3 No CBGs with High Cook's Distance[b]			Model 4 No CBGs with High Studentized Residual[c]		
	β	SE	P Value	β	SE	P Value	β	SE	P Value	β	SE	P Value
Alcohol outlet SAI[d]	0.47	0.05	<0.001	0.46	0.06	<0.001	0.46	0.04	<0.001	0.46	0.04	<0.001
Drug arrests	0.02	0.01	0.01	0.02	0.01	0.06	0.02	0.01	<0.001	0.02	0.01	<0.001
Percent African American	0.72	0.11	<0.001	0.64	0.12	<0.001	0.66	0.08	<0.001	0.64	0.08	<0.001
Median annual household income	-0.03	0.01	0.01	-0.03	0.02	0.14	-0.03	0.01	<0.01	-0.04	0.01	<0.001
Owner-occupied housing	-0.07	<0.01	<0.01	-0.01	<0.01	<0.01	-0.01	<0.01	<0.001	-0.01	<0.01	<0.01
Population density	0.03	<0.01	<0.001	0.03	<0.01	<0.001	0.03	<0.01	<0.001	0.02	<0.01	<0.001

[a]The value (2*p+2)/n, where p is the number of parameters and n is the sample size, was used to identify CBGs with a high leverage.
[b]The value 4/n, where n is the sample size, was used to identify CBGs with a high Cook's distance.
[c]The value 3 was used to identify CBGs with high studentized residuals.
[d]Calculated by summing the inverse network distance from the CBG centroid to the 10 nearest alcohol outlets.

Methods for Chapter 5

A sensitivity analysis was conducted to determine how the cost-effectiveness estimates compare to other published estimates. The analysis used the findings from chapter 3 to determine the association between the natural log of the count of alcohol outlets and the count of violent crime (*IRR*=1.037, *95% CI* 1.024, 1.051, p<0.001) (see Tables A-27 through A-29). This model found substantially lower levels of anticipated effects of the alcohol outlet zoning policies. This is likely because the majority of CBGs that would experience a decrease in alcohol outlets would lose one outlet (see Figure A-40). As ln(1)=0, there is no change associated with this bulk of the decreases in the cost-effectiveness models. This means that using a count to model alcohol outlet access dramatically underestimates the association.

Figure A-40. Number of Alcohol Outlets Removed from CBGs under Cost-Effectiveness Policies

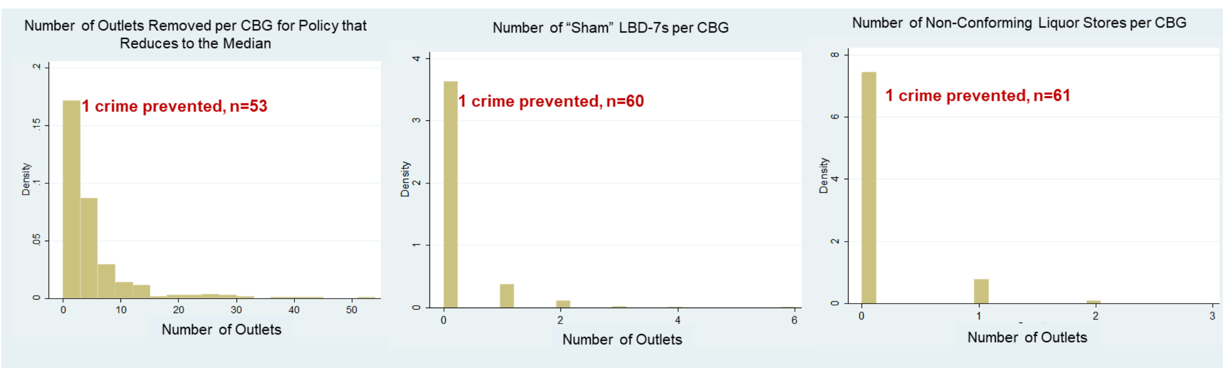


Table A-27. Number of Crimes Prevented by Policy Type Using Counts of Alcohol Outlets and Natural Log Transformation

Policy	Homicide		Aggravated Assault		Rape		Robbery		Total	
	Crimes Prevented	95% CI	Crimes Prevented	95% CI	Crimes Prevented	95% CI	Crimes Prevented	95% CI	Crimes Prevented	95% CI
Reduce alcohol outlet count to CBG median (two outlets)	5	3, 7	117	77, 159	7	5, 9	134	89, 182	263	174, 356
Remove the non-conforming liquor stores in residential zones	0	0, 0	3	2, 4	0	0, 0	2	2, 3	6	4, 8
Remove the "sham" bar/taverns	0	0, 0	16	10, 22	1	1, 1	22	15, 30	40	26, 54
Remove the non-conforming liquor stores and "sham" bar/taverns	1	1, 1	23	15, 31	1	1, 2	28	19, 38	54	35, 73

Table A-28. Costs Saved by Policy Type Using Counts of Alcohol Outlets and Natural Log Transformation

Policy	Homicide		Aggravated Assault		Rape		Robbery		Total	
	Cost Saved	95% CI	Cost Saved	95% CI	Cost Saved	95% CI	Cost Saved	95% CI	Cost Saved	95% CI
Reduce alcohol outlet count to CBG median (two outlets)	6.99	4.60, 9.50	2.52	1.66, 3.41	0.31	0.20, 0.42	3.16	8.56, 17.61	12.99	8.56, 17.61
Remove the non-conforming liquor stores in residential zones	0.48	0.31, 0.65	0.07	0.04, 0.09	<0.01	<0.01, <0.01	0.05	0.03, 0.07	0.60	0.40, 0.82
Remove the "sham" bar/taverns	0.42	0.28, 0.58	0.34	0.22, 0.46	0.05	0.03, 0.06	0.53	0.34, 0.72	1.34	0.88, 1.82
Remove the non-conforming liquor stores and "sham" bar/taverns	1.47	0.96, 1.99	0.49	0.32, 0.67	0.06	0.04, 0.08	0.67	0.44, 0.91	2.68	1.76, 3.65

Table A-29. DALYs Averted by Policy Type Using Counts of Alcohol Outlets and Natural Log Transformation

Policy	Homicide		Aggravated Assault		Rape		Robbery		Total	
	DALYs Saved	95% CI	DALYs Saved	95% CI	DALYs Saved	95% CI	DALYs Saved	95% CI	DALYs Saved	95% CI
Reduce alcohol outlet count to CBG median (two outlets)	88	58, 120	22	15, 30	4	3, 5	4	3, 5	118	78, 161
Remove the non-conforming liquor stores in residential zones	6	4, 8	1	0, 1	0	0, 0	0	0, 0	7	4, 9
Remove the "sham" bar/taverns	5	4, 7	3	2, 4	1	0, 1	1	0, 1	10	6, 13
Remove the non-conforming liquor stores and "sham" bar/taverns	19	12, 25	4	3, 6	1	1, 1	1	1, 1	24	16, 33

Table A-30. Number of Crimes Prevented by Policy Type Using Results from Jennings et al.

Policy	Homicide		Aggravated Assault		Rape		Robbery		Total	
	Crimes Prevented	95% CI	Crimes Prevented	95% CI	Crimes Prevented	95% CI	Crimes Prevented	95% CI	Crimes Prevented	95% CI
Reduce alcohol outlet count to CBG median (two outlets)	12	9, 15	332	238, 407	20	14, 25	415	300, 505	779	561, 952
Remove the non-conforming liquor stores in residential zones	4	3, 5	45	33, 56	2	1, 2	32	24, 40	83	61, 103
Remove the "sham" bar/taverns	3	2, 4	87	65, 109	5	4, 6	113	85, 141	208	156, 260
Remove the non-conforming liquor stores and "sham" bar/taverns	7	5, 9	132	98, 164	6	5, 8	145	108, 180	290	216, 361

Table A-31. Costs Saved by Policy Type Using Results from Jennings et al. (in Millions)

Policy	Homicide		Aggravated Assault		Rape		Robbery		Total	
	Cost Saved	95% CI	Cost Saved	95% CI	Cost Saved	95% CI	Cost Saved	95% CI	Cost Saved	95% CI
Reduce alcohol outlet count to CBG median (two outlets)	17.39	12.32, 21.47	7.15	5.11, 8.75	0.91	0.65, 1.11	9.79	7.06, 11.90	35.24	25.14, 43.23
Remove the non-conforming liquor stores in residential zones	5.50	4.07, 6.89	0.97	0.72, 1.21	0.07	0.05, 0.09	0.75	0.55, 0.94	7.29	5.39, 9.13
Remove the “sham” bar/taverns	4.35	3.22, 5.45	1.88	1.40, 2.34	0.22	0.17, 0.28	2.67	1.99, 3.32	9.13	6.78, 11.39
Remove the non-conforming liquor stores and “sham” bar/taverns	9.76	7.24, 12.20	2.83	2.11, 3.53	0.29	0.22, 0.36	3.40	2.53, 4.24	16.28	12.10, 20.33

Table A-32. DALYs Averted by Policy Type Using Results from Jennings et al.

Policy	Homicide		Aggravated Assault		Rape		Robbery		Total	
	DALYs Saved	95% CI	DALYs Saved	95% CI	DALYs Saved	95% CI	DALYs Saved	95% CI	DALYs Saved	95% CI
Reduce alcohol outlet count to CBG median (two outlets)	220	156, 271	64	45, 78	11	8, 14	12	8, 14	307	217, 377
Remove the non-conforming liquor stores in residential zones	70	51, 87	9	6, 11	1	1, 1	1	1, 1	81	59, 100
Remove the “sham” bar/taverns	55	41, 69	17	12, 21	3	2, 3	3	2, 4	28	57, 97
Remove the non-conforming liquor stores and “sham” bar/taverns	123	92, 154	25	19, 31	4	3, 4	4	3, 5	156	117, 194

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Pamela Trangenstein – Curriculum Vitae

Personal

Born September 7, 1983 in Houston, TX

Education

Johns Hopkins Bloomberg School of Public Health
Doctor of Philosophy, Health, Behavior and Society, expected 2018
Dissertation: Bullets and Booze: Alcohol Outlet Access and Violent Crime in Baltimore, MD
Advisor: Dr. David Jernigan

Johns Hopkins Bloomberg School of Public Health
Master of Public Health, 2014
Capstone Project: Comparison of an Internet-Based Underage Alcohol Survey to the YRBS 2011
Advisor: Dr. Elizabeth Stuart

Washington University in St. Louis
Bachelor of Arts 2005; Major in Psychology
Minors in Printmaking/Drawing and Photography

Selected Work Experience

Center on Alcohol Marketing and Youth **9/15-6/18**
Predoctoral Fellow
Alcohol Outlet Density in Baltimore, MD
These CDC-funded studies aimed to: 1.) Determine the association between alcohol outlet access and several outcomes (e.g., violent crime) and 2.) Determine the number of preventable violent crimes, costs, and disability-adjusted life years with alcohol outlet zoning policies.
Responsibilities:

- Formulated research questions and identified data sources.
- Conceptualized methodological approach to test CDC's recent guidance on measuring alcohol outlet access.
- Conducted analysis, including negative binomial and multiple linear regression in Stata and autoregressive modeling in R.

Key Accomplishments:

- Presented at APHA 2016, Kettil Bruun 2017, and GAPC 2017.
- Secured a new contract after presenting this analysis to local stakeholders.

Global Survey on Alcohol Policy
These two analyses were funded by the World Health Organization (WHO). The first analyzed the 2015 *Global Questionnaire on Progress in Alcohol Policy*, which measured countries' progress in implementing alcohol policy since WHO's *Global Strategy to Reduce the Harmful Use of Alcohol* was released in 2010. The second analyzed data from the 2016 WHO *Global Questionnaire on Alcohol and Health*.
Responsibilities:

- Co-authored chapters summarizing key findings with advisor.
- Cleaned and organized dataset, which included multiple batches of data collection and responses in diverse languages.
- Ran descriptive statistics and presented quantitative data using diverse formats.
- Conducted a theme analysis of the qualitative data on successes and barriers.

Morbidity, Mortality, and Cost of Excessive Alcohol Use in Baltimore, MD
This CDC-funded study aims to generate comprehensive estimates of harms, deaths, and costs attributable to excessive drinking in Baltimore, MD using administrative records from 2013.
Responsibilities:

- Identified free data sources with alcohol-attributable outcomes.
- Requested and managed datasets, including data use agreements where required.
- Devised analysis plan to combine heterogenous data sources using consistent methods.
- Analyzed datasets using alcohol-attributable fractions.

Alcohol Environment in Greenmount East, Midway/Coldstream, and Northwood
This study was funded by Behavioral Health Systems Baltimore and described the alcohol environment in three Baltimore neighborhoods in relation to recent zoning policy changes.
Responsibilities:

- Designed an alcohol outlet observation instrument using previous instruments and peer-reviewed literature.
- Created GIS mapping of the alcohol outlets and their proximity to violent crime, drug arrests, 911 calls for service, and vacant properties.
- Conducted observations of 34 alcohol outlets, including administering the observational survey and documenting conditions with photographs.
- Obtained and summarized violation histories for 34 alcohol outlets.
- Identified alcohol outlets for possible citizen protest.

Conceptual Framework on Alcohol-Related Harms to Others among College Students
This project included a literature review and development of a conceptual framework of alcohol-related harms to others (HTO) experienced by US college students. The literature review was conducted in order to: 1) To determine the knowledge about the prevalence of HTO among college students and 2) To identify gaps in the current literature.
Responsibilities:

- Conducted a literature review using key search terms.
- Synthesized findings of literature review into a conceptual framework.
- Identified gaps in the literature based on current findings.

JHSPH Global Health Established Field Placement **6/16-8/16**
Research Assistant
South African Medical Research Council, 6/16-8/16
International Alcohol Control Study Analyses
There were three analyses using the International Alcohol Control survey data. The first examined support for 10 alcohol policies overall and by key demographics. The second and third investigated the prevalence and determinants of heavy drinking and alcohol problems in Gauteng Province, South Africa.
Responsibilities:

- Led the analyses, including cross tabulations and multiple logistic regression.
- Designed and conducted supplemental analyses like distribution of consumption.
- Developed derived variables like primary drinking location and primary container size using complex coding.

Key Accomplishments:

- Dr. Charles Parry presented these analyses at Kettil Bruun 2017 and GAPC 2017.
- Completed the three analyses in 2 months.

Western Cape Provincial Government, 7/16
Responsibilities:

- Reviewed and supplemented the evidence base in the Western Cape Provincial Green Paper on reducing harmful alcohol use.
- Conducted a multi-attribute utility analysis to prioritize the 42 potential policies in the Green Paper.

Key Accomplishments:

- Finished revising the Green Paper in 1/3 of the allotted time.
- Integrated evidence that helped the Western Cape government anticipate and respond to opposition arguments.

Westat **4/11-8/15**

Study Manager

Diabetes Prevention — Composite State-Wide Estimates of Chronic Disease Risk Factor Control: Prototype for a National Program to Track State and Local Progress in ABCs and Preventative Care Services, 1/15-8/15

Project Manager & Data Preparation Coordinator

This 3-year, 3 million dollar contract aimed to improve CDC's ability to track disease prevention efforts by assembling, combining, and validating existing data sources to produce composite estimates of levels of and trends in the control of diabetes, prediabetes, risk factors, and diabetes-related complications.

Responsibilities:

- Managed project implementation, including budgets, client correspondence, and team meetings.
- Oversaw protocol development and documentation.
- Conducted literature reviews to identify key predictors and outcomes for the analyses.
- Coordinated the data preparation team, which aimed to harmonize and recode heterogeneous datasets into cohesive analytic datasets.
- Identified next steps and priorities for the data preparation team.

Key Accomplishments:

- Assumed the role of data preparation coordinator after 1 month on the team.
- Created key documents to streamline the extensive data preparation process.

Physician Compare, 1/15-8/15

User Acceptance Testing Task Lead

This subcontract funded by the Centers for Medicare and Medicaid aimed to facilitate implementation and support all work related to the Medicare.gov Physician Compare website and public reporting of physician performance data.

Responsibilities:

- Managed a team of 13 website testers, including delegating tasks, supervising implementation, coordinating findings, and providing feedback to staff members.
- Served as the main point of contact for the website developers and the client.
- Held internal trainings to clarify procedures and engage staff.

Balance after Baby Intervention: Phase 2 (BABI2), 9/14-2/15

Project Manager

BABI2 is a randomized clinical trial to determine whether reducing postpartum weight retention in women diagnosed with gestational diabetes reduces risk of type 2 diabetes. BABI2 is a 2 million dollar contract funded by CDC and implemented at Brigham and Women's and the University of Colorado Denver hospitals.

Responsibilities:

- Managed questionnaires and protocol development.
- Prepared and submitted OMB and IRB applications.
- Communicated between clinical site principal investigators and study director.

National Children's Study Western Regional Operations Center (WROC) Contract, 2/13-2/15

Master Trainer

The NCS WROC was a 5-year, 1.4 million dollar contract funded by the *Eunice K. Shriver* NICHD. The WROC was responsible for data collection and training in the 12 western states.

Responsibilities:

- Trained and certified trainers and data collectors.
- Designed and planned trainings.
- Managed physical measures equipment.

Key Accomplishments:

- Consistently rated as very good or excellent on training evaluation forms.
- Key "go-to" contact for physical measures equipment, protocol, and training information.

Westat (Cont.)
<u>National Children's Study Visit/Event and Flow Choreography Contract, 4/11-2/15</u>
Choreography Specialist
The Visit/Event & Flow Choreography Contract of the NCS was a 5-year, 3.3 million dollar contract funded by the *Eunice K. Shriver* NICHD. This contract aimed to identify efficient flows that minimize participant burden and maximize data quality.
Responsibilities:

- Wrote and revised specifications for survey instruments.
- Developed procedural and training materials from a choreography perspective.
- Supported the Study Content Team/Health Measurement Network with developing procedures for new events and activities.
- Authored internal procedures for all choreography development team procedures.
- Produced internal training materials and lead internal team trainings.

Key Accomplishments:

- Promoted to choreography development team coordinator.
- Created well-received computer animations to convey abstract concepts in trainings.

Synergy Enterprises, Inc. **10/10-4/11**
<u>Magnet Schools Assistance Program Technical Assistance Center (MSAP Center) Contract</u>
Senior Research Associate (Deputy Project Director)
This was a 3-year, 3.3 million dollar contract funded by the U.S. Department of Education, Office of Innovation and Improvement (OII). The MSAP Center provides technical assistance to MSAP grantees and the magnet schools community in program development, implementation and evaluation.
Responsibilities:

- Oversaw design and development of MSAP Center website (www.msapcenter.com).
- Supported gap analysis of the 2010 cohort to quantify the grantees' needs.
- Conducted literature reviews to identify website resources.
- Developed databases for needs assessment data, taxonomies and reports.
- Guided newsletter, monthly report, and other deliverable development.

Key Accomplishments:

- Developed and launched the MSAP Center's website in 2 months.
- Authored the MSAP Center Needs Assessment Plan.

University of North Carolina at Chapel Hill **9/09-9/10**
<u>The Natural History of ADHD in a Population-Based Sample (Johnston County Follow-Up Study, JCFU)</u>
Research Assistant/Project Coordinator
JCFU was a 4-year, $500,000 grant funded by NIMH. JCFU aimed to estimate the prevalence, trajectory, risk factors, and impact of ADHD in a rural population.
Responsibilities:

- Administered 50 in-person youth interviews and 51 phone or in-person parent interviews.
- Obtained informed consent and assent.
- Tracked highly transient participants using phone calls, mailings, Internet searches, home visits and a private investigator.

Key Accomplishments:

- Promoted to project coordinator in January 2010.
- Increased number of interviews completed per month by over 50% by streamlining protocols.
- Improved tracking database design to monitor all respondents centrally.

Washington University School of Medicine **2/08-7/09**
<u>National Monitoring of Adolescent Prescription Stimulants Study (N-MAPSS) Grant</u>
Professional Rater II (Project Coordinator)
The N-MAPSS was a 4-year, $1.5 million grant funded by Shire Pharmaceuticals as a FDA requirement to perform market research after the release of Vyvanse©. N-MAPSS identified
prevalence and frequency of misuse, abuse and diversion of prescription medicines.
Responsibilities:

- Authored, piloted, and revised the N-MAPSS Survey.
- Wrote progress reports, detailing progress, issues and lessons learned.

Washington University School of Medicine (Cont.)

- Recruited and surveyed over 400 respondents in 5 N-MAPSS cities.
- Administered 43 Discrepancy Interview Protocols to assess reliability and validity.
- Established and maintained a data management system for over 6,000 surveys.
- Reviewed surveys and provided same-day feedback on protocol adherence.
- Developed study field manual and regulatory binder, including all forms and protocols.
- Monitored field interviewer techniques and work to prevent fabricated data.

Key Accomplishments:

- Finished wave 1 data collection (2,700 surveys) in 3 of the 4 allotted months.
- Invented an organizational system to match wave 2 gift card serial numbers to unique survey IDs, which reduced administrative burden and the number of stolen gift cards.
- Improved city selection algorithm to use pharmacy-reported data instead of parent-reported data to reduce subjectivity and decrease cost.

Windwalker Corporation **12/05-3/08**

Magnet Schools Assistance Program (MSAP) Evaluation and Technical Assistance Contract

Research Assistant/Independent Contractor

This was a 3-year contract funded by OII. The evaluation determined whether MSAP grantees met objectives for desegregation and academic achievement.

Responsibilities:

- Collected, entered, and validated data from applications, interviews, and the Internet.
- Developed taxonomies, operational definitions, coding schemes, and conceptual models.
- Wrote and edited reports, data analysis plans, program evaluations and literature reviews.
- Performed cross tabulations, chi square tests, and logistic regressions for reports.
- Supported program evaluation of rigorous evaluation grantees.
- Provided technical support to grantees as needed.

Key Accomplishments:

- Designed MSAP Performance Measures Guidebook, which was used in Windwalker's marketing portfolio.
- Invited to remain on staff as an independent contractor after relocating to St. Louis in December 2007 to assist with program evaluations.

PEER-REVIEWED PUBLICATIONS

- Parry, CD., **Trangenstein, P.,** Lombard, C., Jernigan, DH., & Morojele, NK. (2016). Support for Alcohol Policies from Drinkers in the City of Tshwane, South Africa: Data from the International Alcohol Control Study. *Drug and Alcohol Review* (in press).
- Parry, CD., **Trangenstein, P.,** Lombard, C., Jernigan, DH., & Morojele, NK. (2016). Identifying Alcohol Problems and Risk Factors Among Adults in South Africa: Data from the International Alcohol Control Study. *International Journal of Mental Health and Addiction* (in press).

REPORTS

- Jernigan, D. & **Trangenstein, P.** (2016). Global Developments in Alcohol Policies: Progress in Implementation of the WHO Global Strategy to Reduce Harmful Use of Alcohol since 2010. World Health Organization. Geneva, Switzerland. Available at: http://www.who.int/substance_abuse/activities/fadab/msb_adab_gas_progress_report.pdf?ua=1
- **Trangenstein, P.**, Eck, R., Greisen, C., & Jernigan, D. (2017). Alcohol Outlets in Greenmount East, Midway/Coldstream, and Northwood Community Statistical Areas. Johns Hopkins Bloomberg School of Public Health, Center on Alcohol Marketing and Youth. Baltimore, MD.

PRESENTATIONS

- **Trangenstein, P.** & Jernigan, D. (2017). Oral Presentation: The Violence Prevention Potential of Reducing Alcohol Outlet Density in Baltimore, MD. Kettil Bruun Society Annual Conference 2017, Sheffield, England; American Public Health Association Conference, Denver, Colorado; Global Alcohol Policy Conference 2017, Melbourne, Australia.
- **Trangenstein, P.** & Jernigan, D. (2016). Poster: Mapping the Unknown: A Conceptual Framework for Understanding the Determinants of Experiencing Alcohol's Harms to Others among College Students. Maryland Public Health Association Annual Conference 2016, Towson, MD; Alcohol Policy 2017, Arlington, VA.
- Graham, J., & **Trangenstein, P.** (2016). Oral Presentation: Environmental Scans as a Tool for Reducing Underage Drinking. Alcohol Policy 2017. Arlington, VA.

AWARDS

- Travel Award, Kettil Bruun Society — June 2018

- First Place, Policy and Practice Research — March 2017
  Johns Hopkins Bloomberg School of Public Health Delta Omega Poster Competition
  The Violence Prevention Potential of Reducing Alcohol Outlet Density in Baltimore, MD

- Gordis Teaching Fellowship — October 2016
  Award to design and develop the course, *Alcohol and Social Disparities: A Public Health Perspective*, which examines alcohol use from ethical, epidemiological, and social justice perspectives. The course is structured in three parts: 1.) Ethical issues in alcohol-related harms, 2.) Alcohol and marginalized populations, and 3.) Alcohol and injustice. This course models how to frame a complex problem from a public health perspective and teaches students to critically engage with social justice concepts. This seminar-format course incorporates guest lectures, small group exercises, case studies, and role plays.

- Global Health Established Field Placement (GHEFP) Award — June 2016
  The GHEFP provided the opportunity to spend 2 months in Cape Town, South Africa, analyzing data from the South African arm of International Alcohol Control Study and developing a Green Paper (i.e., draft policy proposal) for the Western Province.

- Second Place, Policy and Practice Research — February 2016
  Johns Hopkins Bloomberg School of Public Health Delta Omega Poster Competition
  Mapping the Unknown: A Conceptual Framework for Understanding the Determinants of Experiencing Alcohol's Harms to Others among College Students

- Health, Behavior, and Society Scholarship — August 2015
  Johns Hopkins Bloomberg School of Public Health

- Dean's Scholarship — August 2011
  Johns Hopkins Bloomberg School of Public Health

- Dean's List (7 of 8 semesters) — 2001-2005
  Washington University in St. Louis

- Gold Key (2) — 2001
  Scholastic Art & Writing Awards

PROFESSIONALLY-RELATED ACTIVITIES

TEACHING

- Instructor, *Alcohol and Social Disparities: A Public Health Perspective*, Johns Hopkins University School of Public Health, September-December 2017
- Teaching Assistant:
  - *Alcohol, Society and Health*, Johns Hopkins Bloomberg School of Public Health, January-March 2016 & January-March 2017

- *Translating Research into Public Health Programs II*, Johns Hopkins Bloomberg School of Public Health, March-May 2017
    - *Media Advocacy in Public Health: Introduction to Theory and Practice*, Johns Hopkins Bloomberg School of Public Health, March-May 2017
    - *Introduction to Campaigning and Organizing for Public Health*, Johns Hopkins Bloomberg School of Public Health, January-March 2017, July-August 2017
- Guest Lectures:
    - "Epidemiology of excessive alcohol use and related harms" in *The Epidemiology of Substance Use and Related Problems,* Johns Hopkins Bloomberg School of Public Health, November 2017
    - "Excessive alcohol use and individual-level interventions" in *Clinical and Public Health Behavior Change*, Johns Hopkins University, March 2017 & April 2018
    - "Epidemiology and prevention of college drinking" in *Introduction to Health Promotion*, American University, November 2016

OTHER

- Reviewer: Drug and Alcohol Review, Alcoholism: Clinical and Experimental Research, African Journal of Drug and Alcohol Studies
- Chair: Forum on Alcohol Research and Advocacy, Johns Hopkins Bloomberg School of Public Health, August 2015-present
- Professional Membership: American Public Health Association